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Emission Density Zoning Guidebook. A Technical Guide to Maintaining Air Quality Standards Through Land-Use-Based Emission Limits

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Emission Density Zoning Guidebook

A Technical Guide to Maintaining Air Quality Standards Through Land-Use-Based Emission Limits

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16. ABSTRACT

An emission density zoning (EDZ) regulation is an air pollution control strategy that is similar to traditional land use zoning (which controls development density in particular areas) in that EDZ controls air pollution by setting emission density limits (EDLs) for certain areas of land. EDLs restrict the rate of pollutant emission per unit area (such as grams per second per hectare).

This document is step-by-step procedural guide designed to help regional planning and air pollution control agencies set EDLs for sulfur dioxide and particulate matter within a metropolitan area. The EDLs, set through the use of a computer-assisted dispersion model and linear programming package, ensure the attainment and maintenance of the National Ambient Air Quality Standards and compliance with Prevention of Significant Deterioration regulations. Difficult concepts are explained in appendices to the guidebook.

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Area Emission Allocations Atmospheric Diffusion Flux Density Land Development Land Use Linear Programming Particulates Planning Regional Planning Sulfur Oxides Urban Planning Zoning	Air Pollution Control Air Quality Maintenance Emission Density Limits Emission Density Zoning	

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by

Norman F. Kron, Jr., Alan S. Cohen, and Linda M. Mele
Technical Editor: Kathryn S. Macal

Energy & Environmental Systems Division
Argonne National Laboratory
9700 South Cass Avenue
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INTRODUCTION

THE ROLE OF EMISSION DENSITY ZONING

Historically, air pollution control has been on a source-by-source basis. Polluters were required to avoid being nuisances to their neighbors. Those who were nuisances were asked to relocate, shut down, or clean up. As regulations became more sophisticated, limits were placed on the physical characteristics -- such as smoke opacity -- of the pollutants emitted by a source. As long as a pollution source met the emission limitations, it could be located anywhere in the community, provided of course that the existing zoning ordinance requirements were followed.

Since the passage of the Clean Air Act Amendments of 1970, source-by-source air pollution controls have become increasingly popular. Emphasis has been placed on limiting emissions per unit of production (for example, grams of sulfur dioxide emitted per joule of energy generated).* These regulations provide a simple way of turning the social cost of air pollution into a production cost for the manufacturer (and ultimately a cost to the consumer) of pollution-causing products.

However, source-by-source controls have certain limitations. Once a particular emission threshold is reached, reducing pollutant levels below the threshold becomes very expensive or even impossible due to the limits of technological controls. Yet, even with most or all polluters emitting at their thresholds -- with pollution levels of 0-1% of their uncontrolled emissions -- unhealthy pollutant concentrations may occur if several polluters are located near each other. This is where emission density zoning (EDZ) or other emission allocation schemes** can be useful. Such schemes are designed to avoid high pollution levels by placing upper limits on emissions over a geographical area, as opposed to placing limits on individual pollution sources. The generally accepted definition of EDZ is: "... a type of air pollution control regulation in which the maximum legal rate of emission of an air pollutant is based on location, land area, land use zoning, and air quality constraints." (Robson, John, U.S. EPA, personal communication, 1977).

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*Metric units are used throughout this document. Metric/English conversions are provided in Appendix C.

**For definitions of other emission allocation schemes for which the methodology described in this guidebook can be applied to estimate emission quotas, see Brail, et al. (1975b), and Step 25 of this document.

Perhaps the best way to explain how EDZ works is to show its similarities to traditional land use zoning. EDZ may be thought of as an air pollution control regulation that is superimposed upon an existing zoning ordinance. All the land use districts and boundary lines contained in the existing zoning ordinance are retained, but there is an additional restraint on how each hectare of land may be developed. Each hectare is assigned an emission density limit (EDL), which specifies the maximum emission allowed per unit of time per unit of land area (for example, grams of particulates per second per hectare). Any land use permitted by the existing land use zoning ordinance continues to be allowed; however, with EDZ, the source is not allowed to emit more pollutants than the limit allowed for the parcel of land on which it is located.

The concept of emission density limits can be illustrated with an example involving "Cleanair City," a hypothetical city which uses emission density zoning to maintain air quality. Bilgewater Industries (BI) would like to build a slime drying plant in Cleanair City. According to the city's existing land use zoning ordinance, slime drying is only allowed in heavy manufacturing (M-3) districts. The zoning map (Fig. 1) shows that the new BI plant could be located in one of three M-3 districts.

If there were no EDZ regulations, the heavily-polluting slime drying facility could be built in any of the M-3 areas, provided it met applicable source-by-source emission reduction requirements and did not violate air quality standards in Cleanair City. With EDZ in effect, however, there is a second map. This one has the traditional zoning map as its base, but also shows the maximum emissions allowed per hectare of land in each zoning class and each location. Assume that the only important pollutant emitted in slime drying is sulfur dioxide (SO_2); Cleanair City's EDZ ordinance contains a map of its emission density limits for sulfur dioxide, as shown in Fig. 2. As can be seen, the three manufacturing areas have identical traditional zoning classifications, but different EDLs. Some of the factors considered by Cleanair City officials in setting EDLs were industrial location relative to population, local meteorological conditions, and pollutant concentrations due to emission sources already in the area.

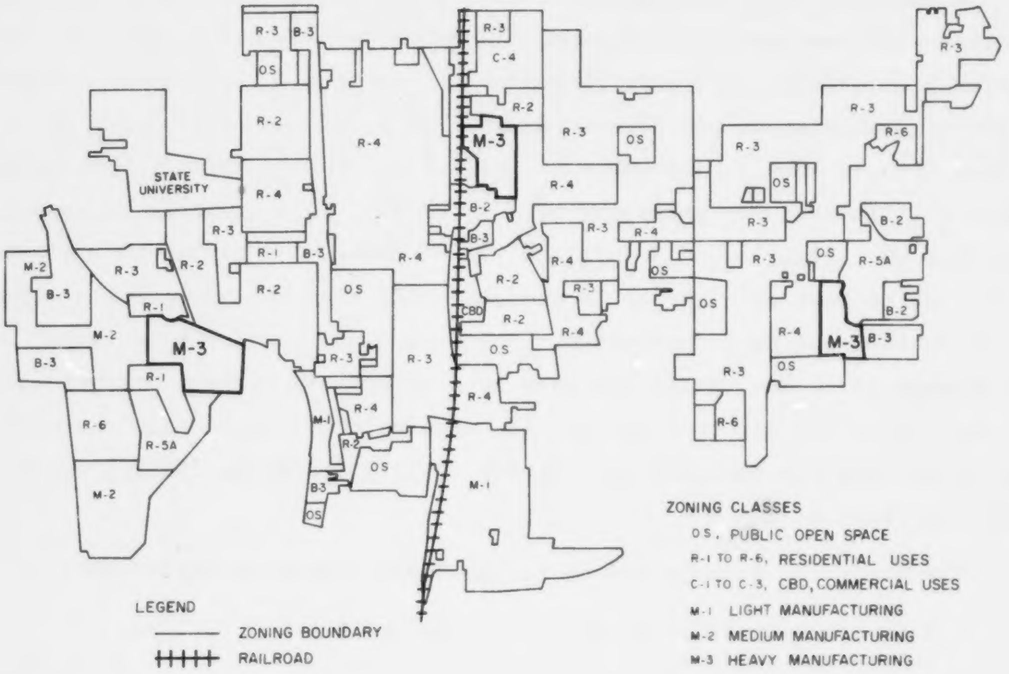
STATE UNIVERSITY
M-3
M-1
M-2
CBD
LEGEND
ZONING BOUNDARY
RAILROAD
ZONING CLASSES
OS, PUBLIC OPEN SPACE
R-1 TO R-6, RESIDENTIAL USES
C-1 TO C-3, CBD, COMMERCIAL USES
M-1 LIGHT MANUFACTURING
M-2 MEDIUM MANUFACTURING
M-3 HEAVY MANUFACTURING

Fig. 1. Cleanair City Zoning Map

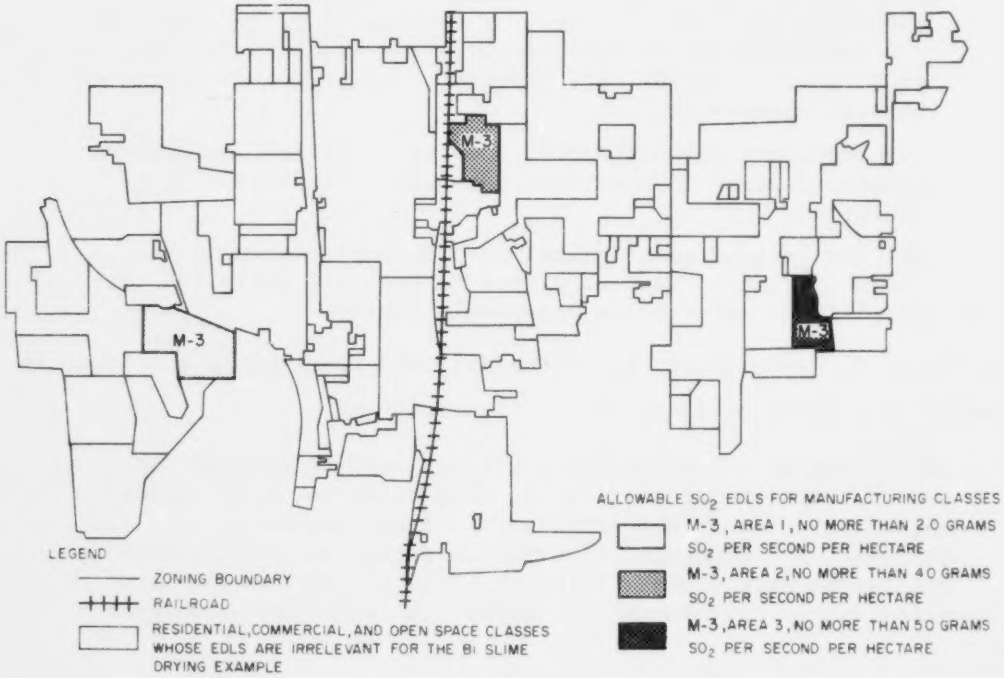
M-3
LEGEND
ZONING BOUNDARY
RAILROAD
RESIDENTIAL, COMMERCIAL, AND OPEN SPACE CLASSES WHOSE EDLS ARE IRRELEVANT FOR THE Bi SLIME DRYING EXAMPLE
ALLOWABLE SO2 EDLS FOR MANUFACTURING CLASSES
M-3, AREA 1, NO MORE THAN 2.0 GRAMS SO2 PER SECOND PER HECTARE
M-3, AREA 2, NO MORE THAN 4.0 GRAMS SO2 PER SECOND PER HECTARE
M-3, AREA 3, NO MORE THAN 5.0 GRAMS SO2 PER SECOND PER HECTARE

Fig. 2. Hypothetical Cleanair City EDL Map

Bilgewater Industries projects that the slime drying plant, even after complying with New Source Performance Standards and all other state and local emission limitations, will emit 20 grams per second (g/s) of sulfur dioxide. Therefore, according to the EDLs shown in Fig. 2, BI must buy either 10 hectares (ha) in Area 1 [allowable SO_2 emissions of 2 (g/s)/ha], 5 hectares in Area 2 [allowable SO_2 emissions of 4 (g/s)/ha], or 4 hectares in Area 3 [allowable SO_2 emissions of 5 (g/s)/ha].* If there is no area where a plant the size of Bilgewater's can be located, BI will have to search for a plant site in another zoning jurisdiction. The effect of the varying acreage requirements is to use up all the land in a given area without overburdening the capacity of the air to clean itself, thus maintaining a healthy atmosphere by meeting the National Ambient Air Quality Standards (NAAQS) established by the U.S. EPA.

The preceding example points to the basic reasoning behind EDZ:

- High concentrations of air pollution are harmful to human health and welfare.
- The air has a certain ability to clean itself of pollutants (assimilative capacity).
- This assimilative capacity depends on local meteorology and the types and concentrations of pollutants in the air. If the concentration of pollutants is too high, the assimilative capacity can be overburdened, possibly resulting in unhealthy conditions.
- By geographically dispersing sources of air pollution, the number of areas of high pollutant concentrations will be minimized.
- EDZ can be used to geographically disperse sources, and therefore can be used as a tool to keep air pollution concentrations at or below acceptable levels.

The U.S. EPA's policy on purchasing land to disperse emissions is currently in a state of flux. As of this writing,

> EPA is taking ever-stronger positions against certain control practices that utilize the dispersing and self-cleansing characteristics of the atmosphere. These practices are: (1) the vertical adjustment of emission points so that pollutants can become more widely dispersed, (2) the hourly adjustment of emissions so that favorable dispersion conditions resulting

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*The figures used here do not conform to those used in the Cleanair City Sample Problem presented in Appendix K.

> from changing weather can be utilized, and (3) procurement of extra land so that the air above it would not be considered "ambient" except for standards relating to visibility... (John Robson, U.S. EPA, personal communication, April 1978).

Given this trend, the authors would like to make it clear to any guidebook user that it may be possible that, even if the EPA officially disallows the purchase of extra land to disperse pollutants, such purchase might be permitted under EDZ provided that it did not lead to localized areas of high pollution concentrations on or off the purchaser's property.

GUIDEBOOK FOR SETTING EMISSION DENSITY LIMITS

Use of the Guidebook

This manual, which may be thought of as an EDZ "cookbook," is a step-by-step guide for formulating emission density limits for a region. An emission density zoning regulation developed using the method presented here will ensure maintenance of local and national ambient air quality standards for sulfur dioxide and particulate matter. The procedure described also can be used to set emission quotas for a number of air quality maintenance strategies, such as emission allocation planning, floating zone emission quotas, district emission zoning (see Brail et al., 1975b), and emission offset strategies (see Step 20).

This guidebook is primarily designed for use by regional planning commissions and air pollution control agencies in metropolitan areas. These two organizations are the most likely to be responsible for setting EDLs because their combined expertise provides most of the manpower resources required by the EDL-setting methodology. In addition, many of the data required are routinely collected by these organizations.* The regional approach is taken because interjurisdictional effects of air pollution can be considered at the regional level.

Although regional planning and air pollution control agencies are assumed to conduct the analyses needed to set EDLs, local governmental agencies will most likely implement the emission density zoning or other air quality maintenance regulation that incorporates the EDLs. The region for which EDLs are developed is assumed to be "typical" in that the local political jurisdictions within it have enacted zoning ordinaces that are being followed with at least some concern for good planning.

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*Other organizations may be given the task of implementing the steps for establishing EDLs but they will most likely have to obtain the cooperation of the regional planning and air pollution control agency personnel.

Another important assumption made in the guidebook is that the "basic EDZ model" is being used (see Steps 17 and 24). The basic EDZ model assumes that the metropolitan region using EDZ would like to maximize the emissions produced in the region while not violating air quality standards. Maximizing emissions is assumed to be a proxy for maximizing economic growth, or at least maximizing flexibility in EDZ administration by knowing the maximum emissions allowed. Flexibility is introduced since a region may select a lower level of emissions. Goals other than maximizing emissions may be pursued by using EDZ, as described by Benesh (1977), but maximizing emissions is the simplest and most easily-achieved objective.

The guidebook is heavily dependent on hand calculations, in order to (1) avoid extensive use of computer programmers and hardware, (2) encourage agencies with few senior staff to devote to EDZ to try the technique by using student help, and (3) make the guidebook understandable to a wide audience. In large regions with high levels of computer expertise, it will probably be desirable to computerize many of the computations.*

The procedure for setting EDLs presented here consists of 25 steps, shown in Table 1, which may be performed simultaneously or sequentially, as shown in Fig. 3. The steps connected horizontally (or diagonally) in the figure must be conducted sequentially from left to right; steps listed vertically may be completed simultaneously. The 25-step process can be aggregated into five kinds of tasks: data collection and analysis (Steps 1-9), computer model testing (Steps 10-13), dispersion modeling (Steps 14-16), linear programming modeling (Steps 17-23), and EDL development (Steps 24-25).

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*In recording data and in calculations maintain accuracy of three (or more) significant figures. To determine three significant figures in a number scan the number from the left and count the first non-zero digit as the first and the next two digits as the second and third significant figures. Round the third digit up if necessary. If at that point you are to the left of the decimal point, add zeros to complete the number; if you are to the right of the decimal point simply stop. Example: 4,321,842 would be 4,320,000, and 0.00087634 would be 0.000876 with three significant figures.

Table 1. Steps Required to Determine Emission Density Limits

Steps	Action	Preliminary Steps[a]	Type of Task
1	Acquire EDZ source data	None	Data Analysis
2	Process EDZ source data	1	
3	Select EDZ receptor location data	1,2,5	
4	Acquire and process meteorological data	None	
5	Acquire and process monitoring station data	None	
6	Acquire and process emission inventory data	1,2	
7	Estimate emissions of exempt sources	1,2,6	
8	Determine stack characteristics	1,2,6	
9	Code and keypunch dispersion model input data	1-8	
10	Acquire dispersion model	None	Model Testing
11	Install dispersion model on computer and check	10	
12	Acquire linear programming package	None	
13	Install linear programming package on computer and check	12	
14	Make air quality dispersion model runs	1-11	Dispersion Modeling
15	Make calibration dispersion model run	1-11	
16	Make right-hand-side dispersion model run	1-11	
17	Set up linear program coefficient matrix	1-3,5	Linear Programming Modeling
18	Estimate objective function coefficients	1-3,5,17	
19	Estimate column and row coefficients	1-11,14,17,18	
20	Estimate right-hand-side coefficients	1-11,15-17	
21	Estimate upper and lower bound coefficients	1-3,5,6,17	
22	Code and keypunch linear programming input data	1-11,14-21	
23	Make linear programming runs	1-22	
24	Analyze linear programming run results	1-23	EDL Development
25	Formulate the EDL strategy	1-24	

[a] Prerequisites listed on pages 8-12 must be completed before work begins on any step.

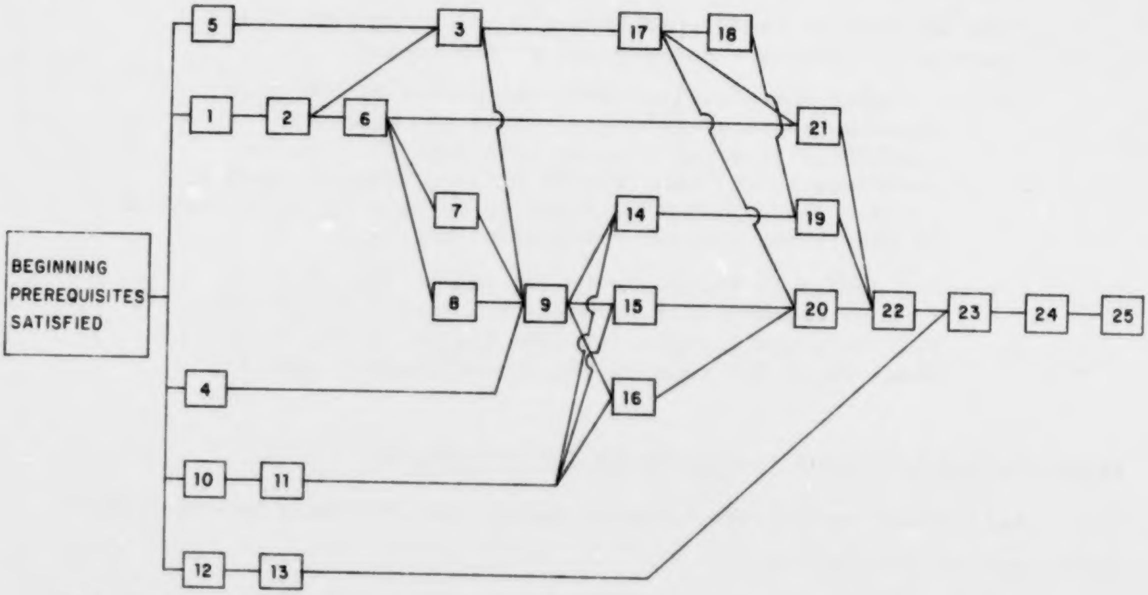

Fig. 3. Flow Diagram of 25-Step Procedure for Setting Emission Density Limits

Selection of Dispersion Model and Linear Programming Package

The EDL methodology set forth in the guidebook uses the Climatological Dispersion Model (version CDMQC)* and the Mathematical Programming System Extended (MPSX) linear programming package. It must be emphasized that other dispersion models and linear programming packages may be used without substantive changes in the results as long as the models have the features listed below.

A dispersion model other than CDMQC must be able to:

- Compute annual average concentrations of SO_2 and particulates.
- Print "culpability lists." These are tables for each receptor that show the pollutant concentration at the receptor resulting from emissions from each source in the region. In other words, these tables show the origins and destinations of the region's air pollutants.

A linear programming package other than MPSX must have:

- A provision to place bounds on the linear programming variables (i.e. EDLs). If these provisions are not available, a person with linear programming expertise should be consulted since the bounds must be incorporated into the model as two inequality constraints and this requires techniques not discussed in the guidebook.
- The ability to handle problems with a nearly 100% dense matrix containing x columns and y rows where:

  x = a number somewhat less than the number of EDZ grid squares covering the region times the number of simplified land use classes (see Step 2). As the guidebook is written, x will be less than or equal to 1,050. (This means there may be as many as 1,050 columns in the linear program coefficient matrix.)

  y = the number of receptors in the region (see Step 3). In most cases y will probably be about 200, but there will be great variability from region to region (this means about 200 rows in the linear program matrix).

Prerequisites for Using the Guidebook for Setting EDLs

Before the 25-step procedure is begun, the following prerequisite tasks must be carried out:

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*The "QC" in CDMQC indicates the addition to the basic CDM of the capability to produce source (Q) contribution (C) lists.

1. Decision to Use or Test EDZ. The decision to use or test EDZ or other emission quota schemes* as air quality maintenance strategies must be made.

2. Resource Commitment. The financial and manpower resources required to carry out the procedures described in this guide must be committed to this purpose. Specifically, the project team will require persons with the skills listed below; some individuals will satisfy more than one requirement.

- Project management -- a person to schedule tasks, check the quality of the work, coordinate efforts of the project staff, budget expenditures, etc.
- Writing -- a person to document the results of the EDL-setting efforts.
- Land use planning/zoning knowledge -- a person familiar with zoning and land use planning techniques.
- Cartographic ability -- preferably a person with expertise in preparing zoning or land use maps and knowledge of the Universal Transverse Mercator (UTM) coordinate system.
- Computer programming - preferably a person with experience with linear programming and dispersion modeling.
- Air pollution control - a person familiar with federal, state, and local air pollution control regulations. Preferably this person will also be familiar with dispersion modeling and linear programming.
- Support services -- persons with keypunching and secretarial skills.
- Data analysis and preparation -- persons to collect, process, and code data. College students in the fields of urban and regional planning and environmental (air pollution) control may be ideal for carrying out these responsibilities.

The total resources committed to the project will vary from region to region but should be less than a person-year of effort for professional personnel and another person-year of effort for support personnel. It should take 6 to 12 months to complete the 25-step procedure for setting EDLs. In addition, the following materials and facilities must be available: office space and supplies, cartographic material, and access to a computer.

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*Step 25 must be consulted if you are intending to try any emission quota scheme other than EDZ.

3. Interagency Cooperation. A cooperative relationship between the regional planning commission and air pollution control agencies must be arranged. Possibly the project team will consist of personnel from both organizations.

4. Literature Review. The literature on emission density zoning, emission quota schemes, and air pollution legislation must be reviewed. Below is a list of documents that should be included in this review.

- Brail, R.K., at al., *Emission Density and Allocation Procedures for Maintaining Air Quality*, U.S. EPA Report EPA-450/3-75-075 (June 1975).
- Cosier, P.C. IV, *Land Use Based Emission Strategies: Their Promises and Problems*, Planning Comment, *12*(2):31-47 (Fall 1976).
- Roberts, J.J., E.J. Croke, and S. Booras, *A Critical Review of the Effect of Air Pollution Control Regulations on Land Use Planning*, from APCA Critical Reviews #3-Air Quality Management and Regional Land Use (1975). Originally appeared in the Journal of the Air Pollution Control Assn., *25*(5):500-520 (1975).
- Robson, John, *Land Use Planning and Air Pollution*, Right of Way, pp. 40-44 (Oct. 1975).
- Benesh, F.H., et al., *A Review of Considerations and Issues in Emission Density Zoning*, U.S. EPA Land Use Planning Office publication (1977).

5. Legal Analysis. A separate study to examine the legal aspects of air quality maintenance strategies should be initiated. The results of this legal study should be a draft of the EDZ or other air quality maintenance regulation which will incorporate the EDLs developed using the guidebook. Background material on the legal issues associated with EDZ are discussed in: Jaffe, M.S., et al., *Legal Issues of Emission Density Zoning*, prepared by American Society of Planning Officials for Argonne National Laboratory and the U.S. EPA, U.S. EPA Report EPA-450/3-78-049 (Sept. 1978).

6. Selection of Sources to be Regulated. In conjunction with the literature review and legal analysis, a prerequisite political, legal or planning decision must be made on which sources are to be regulated by EDZ and which sources are not. Consult legal counsel when making this decision.

In many regions it will be desirable to exempt some sources from the regulation. An "exempt source" is not controlled by EDZ and is not assigned an EDL. Small emission sources such as residences and retail businesses may not require EDZ-type controls because they are relatively clean sources with predictable emissions. Mobile sources, such as cars and trucks, cannot be regulated by EDZ. Dust from agricultural lands is not easily controlled with EDZ. In addition, sources such as electric power plants or municipal incinerators may be exempt because of the small numbers of these sources, the extensive preconstruction review required, and their public service function.

For legal or political reasons it may be desirable to grant "automatic compliance status" to all existing sources. That is, assuming the sources were complying with all other relevant air pollution control regulations, their current per-hectare emission densities would be the EDLs assigned to the land on which the sources are located. These sources need not change their emissions to comply with EDZ, but may not increase their emission densities over the assigned EDL. From the standpoint of the methodology to set EDLs, granting automatic compliance is methodologically the same as exempting a source from the EDZ regulation. Therefore, any methodological reference to exempt sources also refers to sources given automatic compliance status unless specifically stated otherwise.

If you choose to have no exempt sources in your region, you may decide to treat existing sources as "nonconforming uses." In this case, EDLs would be set for lands which have sources already built on them, but the EDLs would be set without regard to the current emissions on the sites. A source on land with EDLs lower than its current emission densities would be expected to lower its emissions, buy more land, or in some way come into compliance within a specified time period or change its emissions if the source was enlarged, sold, or modified. (See Goodman and Freund, 1968.)

Although any particular source will fit into only one of these three exemption categories, there is no methodological reason why a region cannot contain any combination of the three categories of exempt sources. In the EDL-setting procedure "exempt" sources and sources with "automatic compliance status" are treated identically. The guidebook assumes that agricultural, residential, and commercial sources, and all rights of way -- i.e., sources located in the area source zoning district defined in Step 2 --

will be wholly exempt from EDZ. However, even if your region has no exempt sources, the guidebook can still be used to set EDLs.

7. Study of Guidebook. Each member of the project team must read the guidebook (including the appendices) completely before beginning the project. This will ensure that each staff member has a reasonably clear idea of how each step of the methodology relates to the other steps. This will avoid confusion and ensure that outputs from one step are usable as inputs into the following steps. A meeting of the entire staff to review the methodology for establishing EDLs should be held before any steps are initiated.

After these seven prerequisites are fulfilled, you are ready to begin developing your emission density limits. Good luck!

ATMOSPHERIC DISPERSION MODELING AND ITS USE IN EDZ*

An emission density limit (EDL) specifies the rate of pollutant emission for a given unit area of land. A primary reason for setting EDLs is to disperse pollutant sources to avoid "hot spots" where high pollutant concentrations occur. But in order to determine where hot spots currently are in a region or where they might be in the future, one must know where pollutant sources are located, what quantities of pollutants they emit, what type of stacks they have, and where the pollutants travel after they are released into the atmosphere. Because of requirements in the Clean Air Act, the source locations, emission data, and stack characteristics have been collected in state and federal emission inventories. In order to set an EDL, and not violate air quality standards now or in the future, the current and future concentrations of pollutants throughout a region, and the origin of those pollutants, must be known. To obtain this information, air pollution specialists, computer programmers, and meteorologists have developed relatively inexpensive computerized simulation models.

Simulation models for air quality analyses are called atmospheric dispersion (or diffusion) models. These models predict the spatial concentrations of pollutants by converting SO_2 and particulate emissions (measured on a mass-per-unit-time basis such as grams per second) from a number of sources to air pollutant concentrations (measured on a mass-per-unit-volume basis, such as grams per cubic meter) at a number of "receptor points." Figure 4 illustrates some of the factors that affect the dispersion of air pollutants. As can be seen, there are quite a few variables that need to be taken into consideration. Some of the more important of these are discussed below.

Source Data. Dispersion models calculate the regional air pollution concentrations that result from point source emissions, area source emissions, and the combination of these two. Characteristics of point sources needed by dispersion models include locations, emission rates for each pollutant, stack dimensions, and exit gas velocities and temperatures. For area sources, the

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*If there is a doubt about the definitions of words or phrases, consult the Glossary in Appendix A.

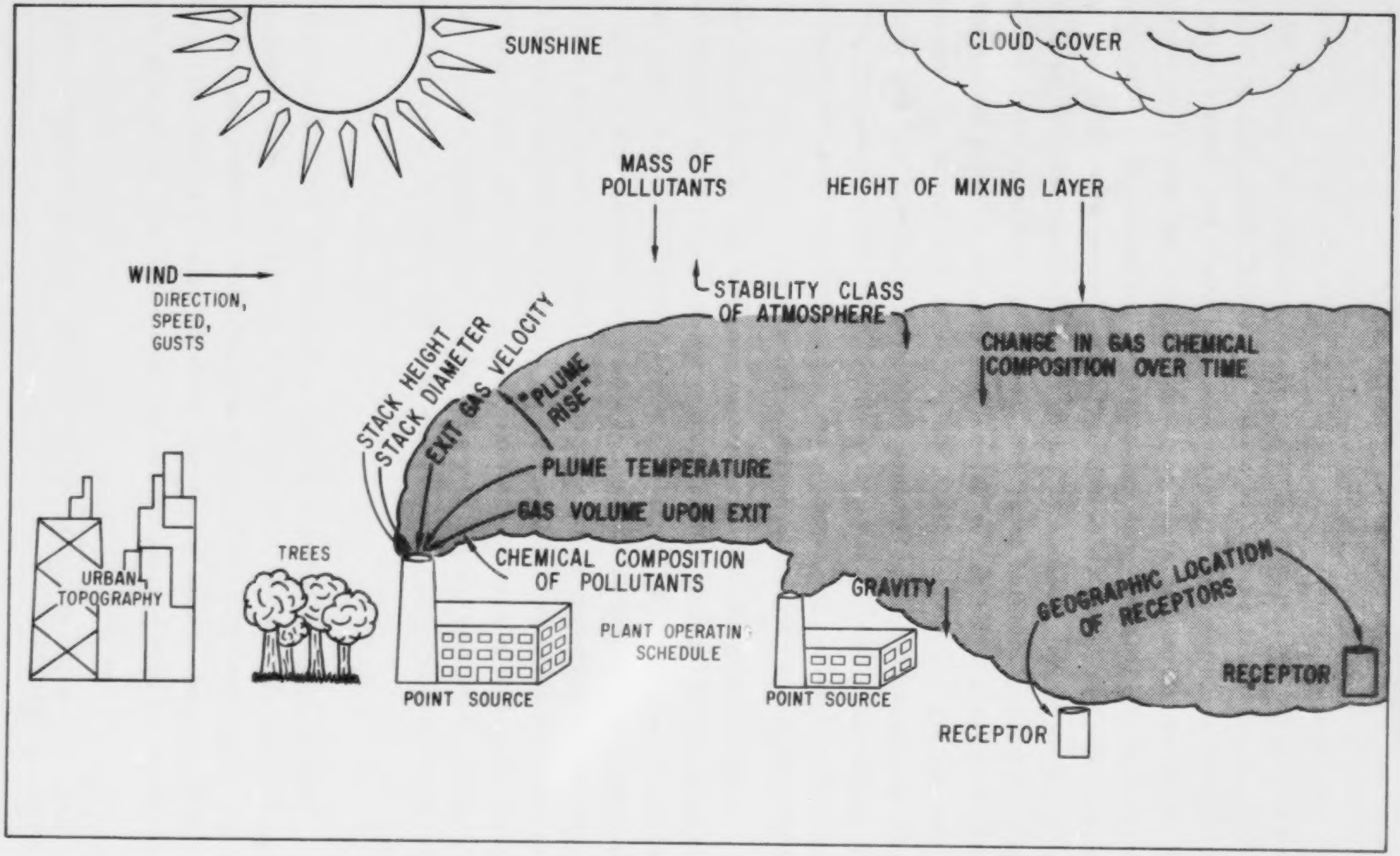
SUNSHINE
CLOUD COVER
MASS OF POLLUTANTS
HEIGHT OF MIXING LAYER
WIND
DIRECTION, SPEED, GUSTS
STABILITY CLASS OF ATMOSPHERE
CHANGE IN GAS CHEMICAL COMPOSITION OVER TIME
STACK HEIGHT
STACK DIAMETER
EXIT GAS VELOCITY
"PLUME RISE"
PLUME TEMPERATURE
GAS VOLUME UPON EXIT
CHEMICAL COMPOSITION OF POLLUTANTS
URBAN TOPOGRAPHY
TREES
PLANT OPERATING SCHEDULE
GRAVITY
GEOGRAPHIC LOCATION OF RECEPTORS
RECEPTOR
POINT SOURCE
POINT SOURCE
RECEPTOR

Fig. 4. Factors in Pollutant Dispersal

models require source locations (via emission grid squares), emission rates, and average stack heights. If future air quality needs to be estimated, the emissions from point and area sources are projected using U.S. EPA-approved techniques and then provided to the dispersion model in the same way as data on current emissions.

Meteorological Data. Meteorological data are highly important to the dispersion model calculations. The data used are of three types: a joint frequency function (JFF), annual average temperatures, and mixing heights. The JFF gives the percentage of the time that a particular combination of wind speed, wind direction, and atmospheric stability occur. There are six wind speed classes, 16 wind directions, and six stability classes, which means that there are 576 possible meteorological situations. Annual average temperatures and mixing heights for the region are derived from standard tables.

Receptor Locations. Dispersion models provide answers to the following questions: Given air pollutant emissions from sources A and B, and the meteorology of the region, what will be the concentration of pollutants at locations X and Y? The locations X and Y are called receptor points, and may be thought of as a combination of real and imaginary air quality monitoring stations. Real monitoring stations are the region's existing air sampling stations. Imaginary monitoring stations are points plotted on a regional map that are used in the dispersion model for simulating air quality measurements throughout the region. Actually all receptor points are treated identically in the model, but real monitoring stations have a special significance -- they provide calibration data.

Dispersion Model Runs. Various combinations of the data described above are required in the five types of dispersion model runs needed for EDZ. Three of the runs are very similar to each other; one of these is the "light manufacturing air quality run." This run computes the pollutant concentrations at each receptor that would result from very high pollutant emission rates in areas zoned for light manufacturing use.* The very large quantities are required to ensure that all possible effects of sources are measured. With lesser quantities, contributions from a source to a receptor may be so small that the effects on the receptor are smaller than the decimal precision of the dispersion models. There are two other air quality runs -- for medium manufacturing sources and heavy manufacturing sources -- which are basically the same as the light manufacturing air quality run but consider emissions for different zoning classes.

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*Light, medium, and heavy manufacturing land use classes are defined in Step 2.

The fourth type of run is the calibration run, which uses monitoring station data to compute a regression line showing the relationship (correlation) between actual and computer-calculated air pollutant concentrations. In addition, the calibration run estimates the background, or naturally-caused,* pollutant concentrations. The fifth type of run, the right-hand-side run, calculates, at each receptor, the air pollution resulting from sources which will not be controlled by EDZ (see Prerequisite 6 in the Introduction).

The results of the dispersion model runs are input to a linear programming package used to determine emission density limits. This procedure is discussed in the next section.

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*Background concentrations also may be due to man-made pollutants originating outside your region.

LINEAR PROGRAMMING AND ITS USE IN EDZ*

Linear programming is a technique for finding the best solution to a problem when considering a number of constraints. A constraint may be defined as a limit or restriction on what may be done. Common constraints in EDZ include air quality standards and emission limits. The use of linear programming in EDZ is best explained through an example.**

Bill Pike, director of the Clean Air Metropolitan Planning (CAMP) Commission, and Barb Fulton, head of the Task Force on Air Pollution, were meeting to discuss progress on the region's EDZ plan.

"Good morning, Bill, how are you today?"

"Pretty good, how about yourself?"

"Fine, thanks. I'd like to discuss our EDZ regulation so that you'll understand how the Task Force came up with the answers we have. I believe we've kept the public and the business people pretty well informed on what to expect, so I doubt that there will be very many arguments when the emission density limits are set. But just in case, I'd like to make sure you understand what's been happening."

"Fine," Bill began, "Why don't I tell you what I think has been going on, and you can tell me if I'm wrong... Let me see, as I recall, you went through a long decision process with the county board chairmen and the Mayors' Confederation to decide on the region's goals relative to air pollution control. When all the shouting was over, they decided that they wanted to maximize their opportunity for economic growth. The EPA said that no matter what, the region couldn't violate air quality standards. Didn't the EPA say there were two standards here?"

"Yes," Barb answered, "Center County and Closeby County are Class III areas but the other four counties are Class II. Because the air quality in the Class II areas is currently much better than it is in the more developed areas of our region, the air quality standard there is more restrictive."

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*If there is doubt about the definitions of any words or phases, consult the Glossary in Appendix A.

**This example explains the "basic EDZ model," which assumes that maximizing emissions throughout the region will maximize opportunity for economic growth. For more information see Step 17 or Benesh et al. (1977).

"OK," he continued, "so your problem was that you had a maximum amount of emissions that could be spewed into the air but at the same time a desire for great economic growth. As I recall, the Task Force concluded that the way to get the best of both worlds would be to maximize the emissions in the area while not violating standards. To do that, you decided to try EDZ - set a maximum emission rate per hectare of land."

"Right," Barb said, "and to set the EDZ emission density limits we've been running a dispersion model and are preparing for some linear programming analyses."

"Well, Barb, I'm not too sure about the technical details. I think you'll have to explain this to me."

"OK. The way it works is that we've run the dispersion model a number of times to generate different kinds of data, all of which are input to the linear program. First, we did three air quality runs, which told us where pollutants were transported after emission. Second, we did a calibration run, which was basically a regression analysis comparing the computed air quality with the real air quality at each of the region's monitoring stations. Then we did something called a right-hand-side run that we used to find the air pollution contributions of sources we wouldn't be covering with EDZ, specifically, things like cars, homes, and small commercial buildings."

"And then this was input to the linear program?" Bill asked.

"Yes, but there were more data. Do you remember when I came to your office to collect the region's set of local zoning maps?"

"Yes."

"Well, we took those and calculated the amount of land zoned for each land use in subareas of the region called grid squares. We took all these data and put them into a format for the linear program, like this."

She began drawing on a note pad and continued, "This is called the coefficient matrix. There's one for SO_2 and another for particulates.* Each is made up of six parts. Three of these are shown on the first row. The columns are numbered sequentially and each column represents a land use class within a grid square. So, for example, column 001 might be for land

---

*See Step 17 for alternate matrix form.

COLUMNS / ROWS	COL0001	COL0002	COL0003	COL0004	• • •	COLYYYY	EQUATION TYPE	RIGHT HAND SIDE
OBJECTIVE FUNCTION							N	
ROW 001							L	
ROW002							L	
ROW 003							L	
ROW 004							L	
ROW 005							L	
ROW006							L	
•••							•••	
ROW XXX							L	
BOUNDS UPPER								
BOUNDS LOWER								

use class M1 within grid square 001, column 002 might be for class M2 in square 001, column 003 might be for class M3 in square 004, and so on. The right-hand-side shows the air quality standard we are trying to achieve minus air pollution contributions made by exempt sources and background. Background is the air pollution caused by natural pollutants like dust. The equation type column shows that the emissions from each grid square to any receptor must be L (less than) the standard.

"The other three parts of the matrix..."

"Wait just a minute," Bill interrupted, "what about this N up here in the equation type column ?"

"Oh..." Barb answered, "That just means that that row represents the objective function of maximizing emissions. In EDZ, the coefficients of the objective function row are the number of hectares in a zoning class in a grid square. So, if column 001 was for M1 land in grid square 001 and the zoning survey showed 20 hectares of land in this situation, the objective function under column 001 would be 20."

"OK, I see. So the objective function row is the fourth part of the matrix," he said.

"Yes, and the fifth and sixth parts are the receptor rows and the bounds section. The receptor rows denote each receptor point used in the dispersion model. So row 001 is for receptor 001, row 002 is for receptor 002 and so on. Here I should explain the columns and rows section.* The dispersion model plus a few calculations provide the transfer coefficients; they indicate the air pollution contribution made by each source to each receptor for a specified emission rate. The columns and rows section is filled in by multiplying the value in the objective function row times the transfer coefficient for the particular land use class in each grid square.

"Do you follow me so far?" she ventured.

"I think so," Bill said, "Each receptor point is a place where the computer calculates the concentrations of air pollutants. And each row in the matrix represents a receptor point."

"Right."

"And the RHS at the end of each row shows the maximum air pollution that can be added to each receptor without violating standards. So, if you knew how much pollution went from each land use to each receptor, then you would know if the standards at the receptor would be violated."

"Right again," Barb replied, "the way that it is done is to calculate the transfer coefficients I mentioned earlier. These numbers tell you that if X amount of pollutant is emitted at location A, then Y concentration of pollutant occurs at location B."

"I see, so location A is a source and B is a receptor."

"Yes, and the system of grid squares that we set up over the entire metropolitan area shows the locations of the sources."

"How's that?"

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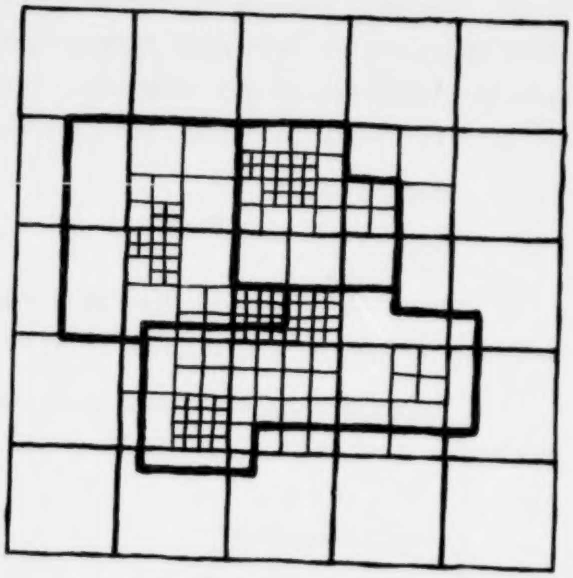
*Sometimes called the "A matrix."



Barb sketched the boundary of the CAMP region and drew a system of grid squares over it. "Here's our region," she said, "and here are the grid squares. Now when an individual square contains pollution sources, the pollutants emitted travel according to our region's topography and meteorological conditions. In our air quality dispersion model run, we treated each grid square as single source rather than as a group of little sources. When each square is treated as a single source, each land use within the square can be thought of as a contributor to the total pollution coming from the square."

"Oh, so if the emissions from each source to a receptor are added across a row, the total must be less than the RHS to avoid violating standards."

"Exactly," Barb continued, "that's what the equation type column says. The air pollution levels at any receptor resulting from all pollution sources in the region can't be any higher than those allowed by the air quality standards. If they are higher, then we're violating the pollution regulations.

"The upper and lower bounds show the maximum and minimum emission rates that can occur per hectare of each land use in each grid square. These upper and lower limits are calculated from projections, current conditions, and reasonable expectations.

"The contents of the coefficient matrix are put into the computer, which then provides us with an optimal solution - the one best way for setting emission density limits, if there is one."

"What kind of answer will the computer give you?" Bill asked.

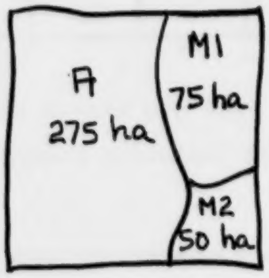
"It will tell us the maximum emission rates per hectare for each land use class in each grid square that can be allowed without violating air quality standards at any receptor. From there we analyze the results, see if they're reasonable, map, and implement."

"That's all?"

"That's all."

"But," Bill asked, "how does the machine pick out the maximum allowable emissions, or the maximum or minimum anything for that matter?"

"Imagine this is a four square kilometer grid square and that there are three land use classes in it like this," Barb said.



M1 = light manufacturing zone
M2 = medium manufacturing zone
A = area sources not subject to EDZ control

"The equation to maximize emissions is called the objective function and it is:

$$\text{Objective function: Max } Z = 75E_1 + 50E_2$$

"This says that we want to maximize total emissions -- that's Z -- which are equal to the hectares of M1 land times the emission density limit for M1, plus the hectares of M2 land times the emission density limit for M2."

Bill queried, "The 75 in the equation, is that the hectares of land in land use class M1?"

"Yes, and the 50 represents the hectares of land zoned M2."

"But, what happened to the 275 hectares in class A?"

"Oh, I forgot to point out that I assumed those sources were exempt from EDZ regulation," she explained.

"But, why should they be exempt?"

"Most area sources -- like residences, retail businesses, and cars -- are too small to be worthwhile regulating with EDZ."

"OK, I understand. Go on."

"Now this gets a little complicated, so let's say there are only two receptors where air quality is estimated, to simplify things." She wrote down two more equations right under the first one:

Objective function: $\text{Max } Z = 75E_1 + 50E_2$

Subject to constraints:

$$75(0.3)E_1 + 50(0.2)E_2 \leq 80-35$$
$$75(0.4)E_1 + 50(0.1)E_2 \leq 80-40$$

"These equations are the air quality constraints for the two receptors. In general, an air quality constraint says that the air pollution at a receptor caused by sources located in land use class M1 plus the air pollution at the same receptor caused by sources in land use class M2 must be less than or equal to--or, in compliance with--the air quality standards at the receptor minus the contribution to air pollution from exempt and background sources. In this example I used the SO_2 annual primary standard of 80 micrograms per cubic meter. The 35 and 40 are hypothetical contributions to air pollution from the exempt sources in land use class A plus any background concentrations of SO_2 in the area. Like before, the 75 and 50 are the number of hectares of land zoned for M1 and M2. The numbers 0.3, 0.2, 0.4, and 0.1 are hypothetical transfer coefficients."

Bill interjected, "Do you mean for every gram of SO_2 emitted per second in each hectare in the M1 area you'd expect air pollution at receptor 1 to increase by 0.3, and at receptor 2 by 0.4 micrograms per cubic meter?"

"Right."

"So then," he continued, "A gram of emissions per second from an M2 hectare would increase pollution at receptor 1 by 0.2 and receptor 2 by 0.1 micrograms per cubic meter."

"Exactly. Remember the upper and lower bounds?" Bill nodded. "Good, these were limits on the allowable emission rates per hectare (or the emission density limits) that reflect technical and possibly political considerations. Let's say that the allowable emission rate per hectare for M1 -- "E_1" -- must be between 0.5 and 3.5 and the limits for the M2 area -- "E_2" -- are 2 and 6. The bounds equations are written like this."

$$\begin{aligned}
&\text{Objective function:} && \text{Max } Z = 75E_1 + 50E_2 \\
&\text{Subject to:} && 75(0.3)E_1 + 50(0.2)E_2 \leq 80-35 \\
& && 75(0.4)E_1 + 50(0.1)E_2 \leq 80-40 \\
&\text{Bounds:} && 0.5 \leq E_1 \leq 3.5 \\
& && 2.0 \leq E_2 \leq 6.0
\end{aligned}$$

"The problem is to find the values of the emission density limits -- E_1 and E_2 -- that will maximize the objective function and obey all the constraint equations. Let's simplify the equations." Barb did a few calculations and then wrote:

$$\begin{aligned}
&\text{Objective function:} && \text{Max } Z = 75E_1 + 50E_2 \\
&\text{Subject to:} && 22.5E_1 + 10E_2 \leq 45 \\
& && 30E_1 + 5E_2 \leq 40 \\
&\text{Bounds:} && 0.5 \leq E_1 \leq 3.5 \\
& && 2.0 \leq E_2 \leq 6.0
\end{aligned}$$

"OK, I think I understand," Bill interrupted, "but how do you find the solution?"

"This is easiest to explain by looking at this diagram. Now, Bill, if you'll look at this graph I just drew, you'll see that all the points between A, B, C, and D will give values that won't violate the air quality standards or the upper and lower bounds."

"Wait a minute. I lost you."

"Let's look at the first air pollution constraint." Barb pulled out the paper she'd written the equations on.

emission density limits) that reflect technical and possibly political considerations. Let's say that the allowable emission rate per hectare for M1 -- "E_1" -- must be between 0.5 and 3.5 and the limits for the M2 area -- "E_2" -- are 2 and 6. The bounds equations are written like this."

Objective function: $\text{Max } Z = 75E_1 + 50E_2$

Subject to: $75(0.3)E_1 + 50(0.2)E_2 \leq 80-35$

$75(0.4)E_1 + 50(0.1)E_2 \leq 80-40$

Bounds: $0.5 \leq E_1 \leq 3.5$

$2.0 \leq E_2 \leq 6.0$

"The problem is to find the values of the emission density limits -- E_1 and E_2 -- that will maximize the objective function and obey all the constraint equations. Let's simplify the equations." Barb did a few calculations and then wrote:

Objective function: $\text{Max } Z = 75E_1 + 50E_2$

Subject to: $22.5E_1 + 10E_2 \leq 45$

$30E_1 + 5E_2 \leq 40$

Bounds: $0.5 \leq E_1 \leq 3.5$

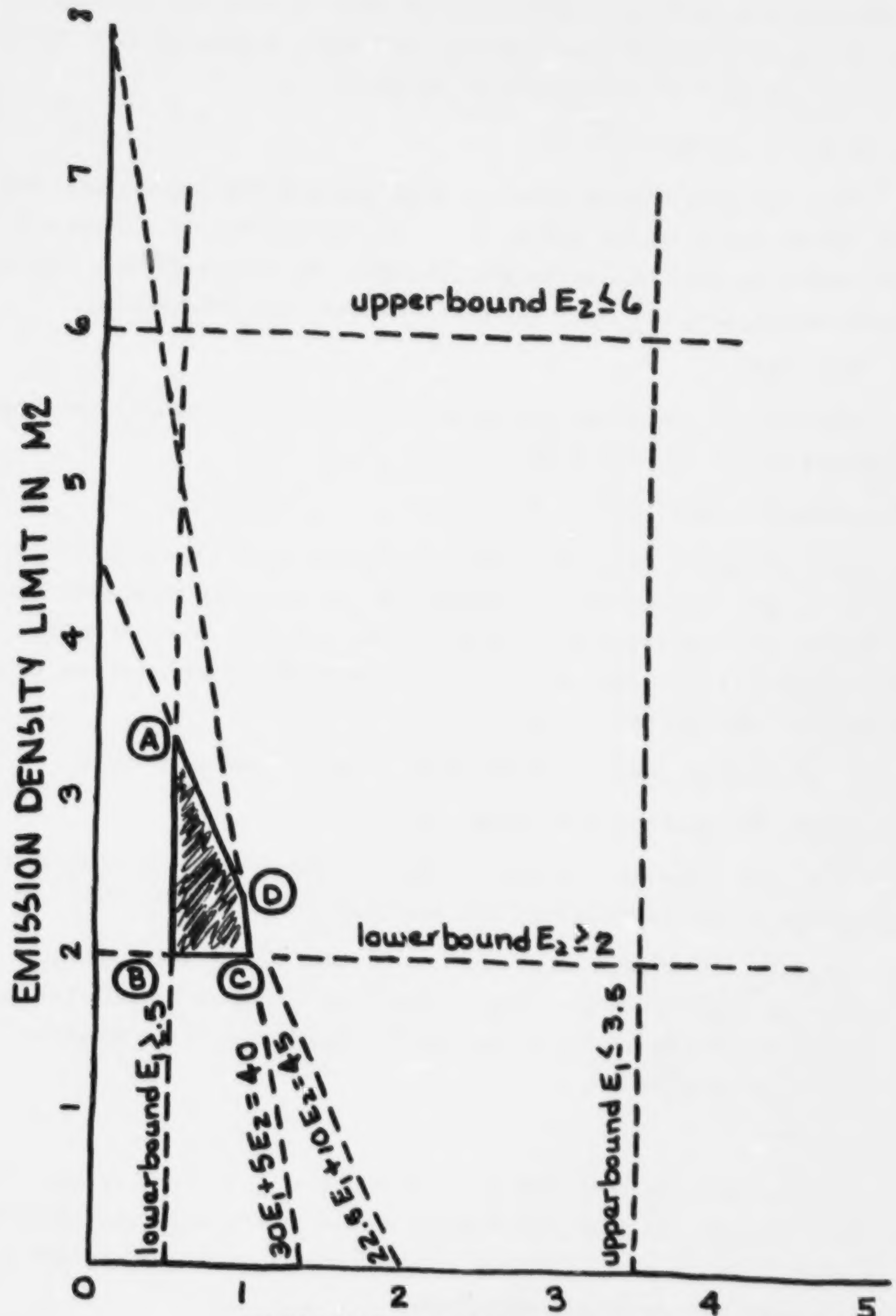
$2.0 \leq E_2 \leq 6.0$

"OK, I think I understand," Bill interrupted, "but how do you find the solution?"

"This is easiest to explain by looking at this diagram. Now, Bill, if you'll look at this graph I just drew, you'll see that all the points between A, B, C, and D will give values that won't violate the air quality standards or the upper and lower bounds."

"Wait a minute. I lost you."

"Let's look at the first air pollution constraint." Barb pulled out the paper she'd written the equations on.


EMISSION DENSITY LIMIT IN M2
EMISSION DENSITY LIMIT IN M1
0
1
2
3
4
5
6
7
8
upperbound $E_2 \leq 6$
lowerbound $E_2 \geq 2$
lowerbound $E_1 \geq .5$
$30E_1 + 5E_2 = 40$
$22.5E_1 + 10E_2 = 45$
upperbound $E_1 \leq 3.5$
Ⓐ
Ⓑ
Ⓒ
Ⓓ

Twenty-two-point-five times E_1 plus 10 times E_2 must be less than or equal to 45. Here I've drawn the equation 22.5 times E_1 plus 10 times E_2 is equal to 45," she said as she pointed to the graph.

"O.K., I see that."

"Now, any points below this line will satisfy this constraint. For example, let's take E_1 as 0.4 and E_2 as 3. As you can see, 22.5 times 0.4 plus 10 times 3 is equal to, let's see, 39, which is definitely less than 45. But you'll notice that 0.4 and 3 can't be an answer for this problem."

"Why not?"

"Because it's an infeasible point since it doesn't satisfy the lower bound constraint for E_1; 0.4 is too low."

"I think I see," he hesitated.

Barb continued, "Why don't you take a point on the graph inside the area A, B, C, and D and convince yourself that all the constraints are satisfied. You'll see that every point works. Then, take points outside the boundary and you'll find that none of those points work. At least one of the constraints is violated every time."

A few minutes later, Bill muttered, "I see, I see -- it works."

"Good, I'm glad you understand now."

"Yes, now I see why the answer must be a point in the area A, B, C, and D, but how do you find the one that maximizes emissions?"

"Luckily, there is a simple way for finding the optimal solution. It's called the simplex method. But, rather than trying to explain the whole method, it will be easier to explain the key property the computer uses to solve the problem quickly."

"Yes?"

"The optimal solution must be a corner point. If there is more than one optimal solution, at least two must be corner points which are adjacent to each other. So, we need only look at the corner points A, B, C, and D and find the one that maximizes emissions."

"OK, how?"

"Well, let's list the corner point solutions." Barb began to make more calculations.

"I know what you are doing. You're solving for the values of E_1 and E_2 at the intersections..er, the corner points," Bill said proudly.

"I see you have the right idea. Well, here we are."

Corner Point	Value of objective function
Point A ($\varepsilon_1 = .5,\ \varepsilon_2 = 3.4$)	$Z = 75(.5) + 50(3.4) = 208$
Point B ($\varepsilon_1 = .5,\ \varepsilon_2 = 2$)	$Z = 75(.5) + 50(2) = 138$
Point C ($\varepsilon_1 = 1,\ \varepsilon_2 = 2$)	$Z = 75(1) + 50(2) = 175$
Point D ($\varepsilon_1 = .9,\ \varepsilon_2 = 2.4$)	$Z = 75(.9) + 50(2.4) = 188$

"As you can see, the optimal solution is at point A since this produces the maximum value for the objective function."

"Do you mean the emission density limits of 0.5 for the M1 area and 3.4 for the M2 area will result in maximum emissions?"

"Yes. Now if you drew the equation 75 times E_1 plus 50 times E_2 equals 208 on the graph I drew before, you'd see that it would intersect the feasible region at point A. Any value of the objective function greater than 208 will result in a line that does not cross the feasible region, which means all the points on the line violate one or more constraints."

"I understand now. But if you can do all this figuring on a note pad, why do you need the computer model?"

"Well, my example has only two land use classes, two receptors, and one grid square. In our metropolitan area we are using three land use classes and several hundred receptors and grid squares. The problem is rather large to be done by hand."

"I see. Is there anything more?"

"Do you see how the technique works?" she asked.

"Yes, and it looks OK to me."

"Excellent. Then why don't we meet again this time next week and talk about our progress with the linear programming?"

"That sounds all right to me. See you then."

STEP 1: ACQUIRE EDZ SOURCE DATA

SUMMARY

In Step 1 you will assemble the data needed to produce a list of EDZ sources and their characteristics. The following substeps are involved in acquiring EDZ source data:

Step 1A: Acquire or Produce a General Regional Map
Step 1B: Identify UTM Coordinates in the Region
Step 1C: Collect Zoning Maps and Ordinances

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

As can be seen in Fig. 5, the only preliminary steps for Step 1 are the prerequisites discussed in the Introduction. The skills, data, and hardware required for Step 1 are summarized in Table 2.

STEP 1A: ACQUIRE OR PRODUCE A GENERAL REGIONAL MAP

The product of Step 1A is a wall size regional map showing the boundaries of:

- the region,
- political jurisdictions in the region,

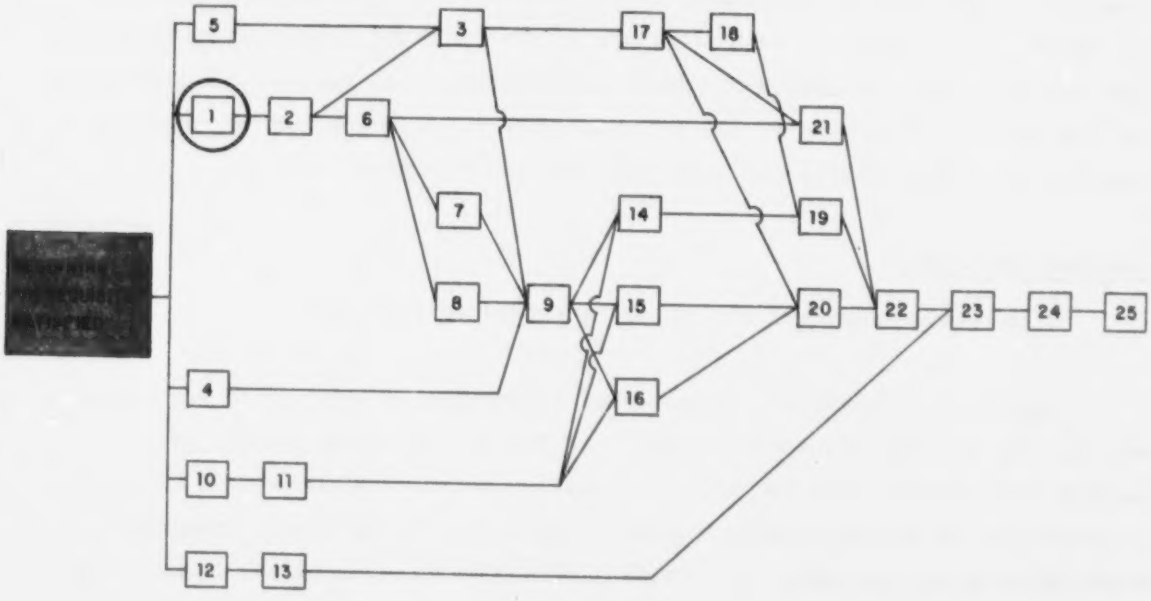


Fig. 5. Prerequisites for Step 1

Table 2. Resource Requirements for Step 1

Necessary Skills[a]	Necessary Data	Data Sources	Necessary Hardware
Land-Use Planning Secretarial Cartographic	Prerequisites	Introduction	Cartographic Supplies
	Regional Boundaries	Introduction	
	Air Quality Standards	Introduction	
	Jurisdictions with Zoning Powers	State	

[a] First on list directs this step.

- natural physical barriers to development, and
- areas with different air quality standards (for example, Class I, II, and III air quality maintenance areas).

Detailed descriptions of each of these map features are provided below. Other information (such as streets and highways) may be included but is not required. An example of a general regional map is shown in Fig. 6.

Before you begin to draw a map, check to see if a useable map has already been compiled [by groups such as regional planning agencies, regional air pollution control authorities, transportation authorities, the U.S. Geological Survey (USGS), and metropolitan special districts]. Any large-scale regional map can be used provided it shows regional and political boundaries, barriers to development, and areas with different air quality standards. If a base map with only one or two of these items can be located, then you will have to add the missing information. The most useful base maps are the USGS 7 1/2 minute (7 1/2") topographic maps, which can be fastened together to form a single map covering the entire region.

Constructing a Map

A wall-size regional map may be prepared as follows:

Regional Boundaries. Examples of boundaries of the region for implementing EDZ are the Standard Metropolitan Statistical Area (SMSA), Air Quality Maintenance Area (AQMA), Air Quality Control Region (AQCR), or the jurisdiction of the regional planning commission. In an ideal situation these boundaries coincide. Determining the appropriate regional boundary is a basic political decision which, for the purposes of this guidebook, is

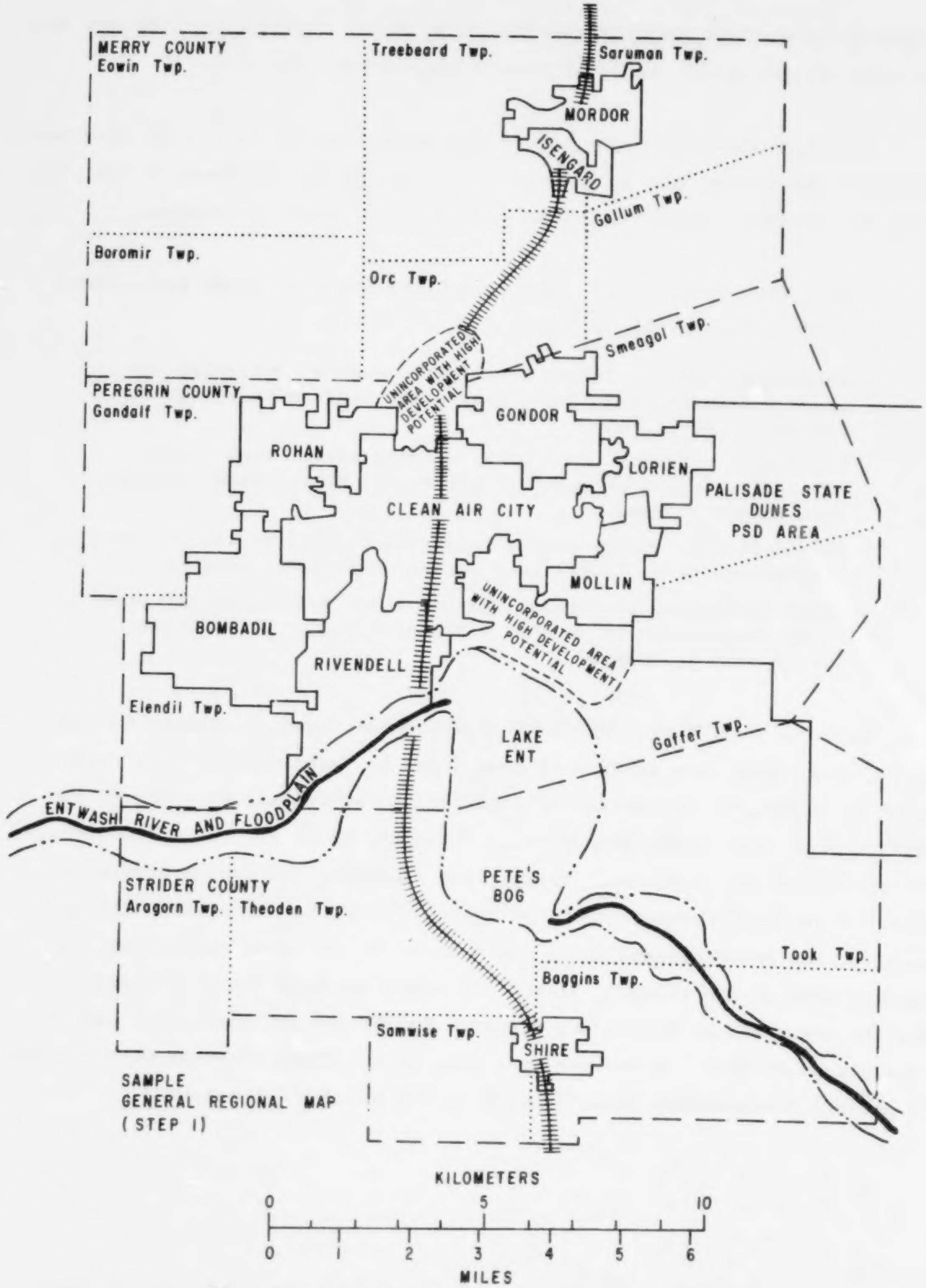

MERRY COUNTY
Eowin Twp.
Treebeard Twp.
Saruman Twp.
MORDOR
ISENGARD
Gollum Twp.
Boromir Twp.
Orc Twp.
Smeagol Twp.
UNINCORPORATED AREA WITH HIGH DEVELOPMENT POTENTIAL
PEREGRIN COUNTY
Gandalf Twp.
ROHAN
GONDOR
LORIEN
PALISADE STATE DUNES PSD AREA
CLEAN AIR CITY
MOLLIN
BOMBADIL
RIVENDELL
UNINCORPORATED AREA WITH HIGH DEVELOPMENT POTENTIAL
Elendil Twp.
LAKE ENT
Gaffer Twp.
ENTWASH RIVER AND FLOODPLAIN
PETE'S BOG
STRIDER COUNTY
Aragorn Twp.
Theoden Twp.
Took Twp.
Baggins Twp.
Samwise Twp.
SHIRE
SAMPLE GENERAL REGIONAL MAP (STEP 1)
KILOMETERS
0
5
10
0
1
2
3
4
5
6
MILES

Fig. 6. Example of General Regional Map

assumed to be part of the prerequisites to Step 1. If this decision has not been made, determine the regional boundaries before continuing.

Political Jurisdictions. After the boundaries of the region have been determined and mapped, the boundaries of each political subdivision that has zoning powers (municipalities, townships, counties) must be mapped.

Development Constraints. Next, identify areas in which development is restricted or impossible, such as:

- Waterways: rivers, lakes, reservoirs, swamps, wetlands, and flood plains of significant land area, where development is currently restricted.
- Unsuitable terrain: mountains, sloping areas, rock zones, cemeteries, areas of mudslide potential, etc., where development is not allowed.
- Permanent open space: state, county, and local parks; beaches; federal and state facilities; forest preserves; zoos; etc.
- Other nondevelopable areas: special local conditions may preclude development on certain parcels of land. These areas should also be mapped.

Areas with Different Air Quality Standards. Certain states and the federal government have designated some areas as "maintenance areas" and others as requiring "prevention of significant deterioration" (PSD) in air quality. U.S. EPA regulations provide for three basic PSD classifications.* The regulations allow states, federal land managers, and Indian governing bodies to reclassify areas under their jurisdiction to accommodate the social, economic, and environmental needs and desires of the local population. A complete list of the Class I, II and III areas for each state is available from the state EPA or equivalent agency. Boundaries of Class I, II and III areas are to be drawn on the regional map, as are those of areas with special air quality designations established by state or local governments.

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*For detailed information on these regulations, see the Clean Air Act Amendments of 1977.

STEP 1B: IDENTIFY UTM COORDINATES IN THE REGION

The data to be collected during this substep consist of the Universal Transverse Mercator (UTM) coordinates that are used in the region. The use of UTM coordinates is recommended because the locations of point and area sources in many emission inventories are given in UTM coordinates and the UTM system is available nationwide.*

The UTM coordinate system, developed by the U.S. Army as a method to precisely locate any point in the world, is much like the latitude and longitude system. Every point has a unique set of east-west and north-south coordinates, called "eastings" and "northings," respectively. All UTM coordinates are in metric units (meters).

Unlike latitude and longitude, which have only two "baselines" -- the equator and the central meridian at Greenwich, England -- there are many UTM baselines. In the northern hemisphere, the equator is the baseline for northings. This means that the northing value at the equator is zero, and increases as one travels north. But eastings have baselines every 6° of longitude, so there are baselines at 3°, 9°, 15°, ..., *63°*, *69°*, *75°*, *81°*, *87°*, *93°*, *99°*, *105°*, *111°*, *117°*, *123°*, *129°*, 135°, ..., and 177°.** Each of these meridians has an easting value of 500,000 m, with points east of the meridian having easting values greater than 500,000 m, and those west of the meridian, less than 500,000 m. The 6° grid zones avoid major deformation of the earth's surface when its shape is transferred from a rounded to a flat surface. Consult Fig. 121 in Appendix E to determine if there is a UTM grid junction in your region.

UTM coordinates may be found on U.S. Geological Survey topographic maps, which are available at a nominal cost from: Branch of Distribution, U.S. Geological Survey, 1200 S. Eads St., Arlington, VA 22202 (Telephone: 703-557-2751), for areas east of the Mississippi; or Branch of Distribution,

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*Other Cartesian coordinate systems (such as state plane coordinates) may be used if their use is well established in the region and the origin is located to the southwest of the region such that all locations within the region have positive x and y coordinates. Systems such as latitude and longitude can *not* be used (see Appendix F).

**Numbers in italics are those relevant to the contiguous 48 states.

U.S. Geological Survey, Box 25286, Federal Center, Denver, CO 80225 (Telephone: 303-234-2351), for areas west of the Mississippi.

The USGS maps will look like the examples in Fig. 7. To read the UTM coordinates on a USGS topographic 7 1/2" map, find the easting and northing marks (usually in blue or black print). These are circled on the top map. The 7 1/2" maps show the location of UTM coordinates every 1000 m with the numerical values of the coordinates provided in at least one corner of the map. The easting values are provided on the top and bottom. For example, in the upper map in Fig. 7, the coordinate labeled $^{7}61^{000\text{m}}$ E is the easting value of 61,000 m. Similarly, the northing coordinate $^{42}52^{000\text{m}}$ N found on either side of the map is read as 52,000 m. For the EDZ analysis the small numbers preceeding the coordinate value may be ignored. On some maps the small zeros are not printed, as shown on the bottom map; in this instance the coordinate $^{45}85$ is read as a northing of 85,000 m.

STEP 1C: COLLECT ZONING MAPS AND ORDINANCES

Since EDZ assigns different emission density limits for each land use class and the intended uses of land are reflected in zoning ordinances or land use plans, a zoning survey must be conducted.* This survey will produce a set of maps showing the zoning classes of every (or nearly every) hectare of land in the region. It is possible that all the maps will be combined to form a single zoning map covering the entire region. But this can be time consuming and therefore is not necessarily desirable.

Data Sources

The primary sources of data for a zoning survey are zoning maps and ordinances. In addition, a large map of the study region with clearly defined landmarks is an essential aid (a copy of the general regional map may be used here). The addition of roads would increase its usefulness. Zoning maps can be found in many forms, some of which are listed below in decreasing order of usefulness:

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*For the EDZ analyses zoning ordinances are recommended for use over land use plans since zoning ordinances are legally adopted, state-sanctioned, police-power regulations that have force of law whereas the land use plans typically have minimal legal authority. The discussion of a zoning survey is adapted from Cohen et al. (1971).

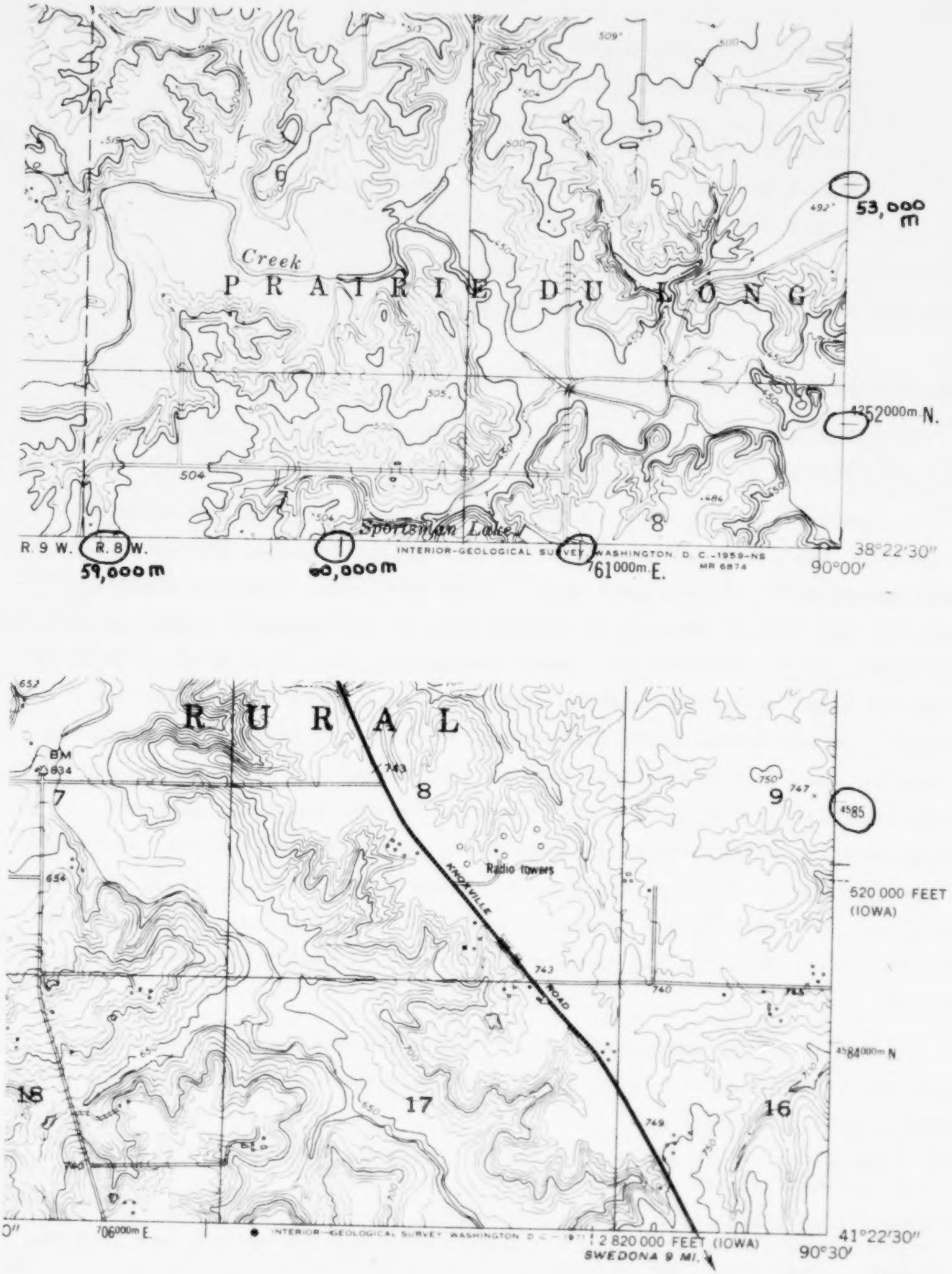
Creek
PRAIRIE DU LONG
6
5
7
8
Sportsman Lake
504
505
486
492
509
R. 9 W.
R. 8 W.
59,000 m
60,000 m
INTERIOR-GEOLOGICAL SURVEY WASHINGTON D.C.-1959-NS
MR 6874
761000m E.
90°00'
38°22'30"
4252000m N.
53,000 m
RURAL
BM 634
7
8
9
743
750
747
4585
Radio towers
KNOXVILLE ROAD
520 000 FEET (IOWA)
740
4584000m N
18
17
16
749
706000m E.
INTERIOR—GEOLOGICAL SURVEY WASHINGTON D.C.—1971
2 820 000 FEET (IOWA)
SWEDONA 9 MI.
41°22'30"
90°30'

Fig. 7. Examples of USGS 7 1/2" Maps

- Composite* zoning map of the entire region.
- Composite zoning map of counties within the region.
- Zoning maps of municipalities including, if applicable, their extraterritorial jurisdictions.
- Zoning maps of county unincorporated areas.
- Zoning maps of township unincorporated areas.

Of course, the more recent the data, the more likely it is that the data are accurate and the more accurate, the better.

Recommended Data Collection Methods

The hierarchy of data types discussed above suggests that a systematic data acquisition procedure can greatly reduce cost and effort.

Composite zoning maps are usually developed for planning purposes. Therefore, the principal sources of these maps are regional and county planning agencies.** If composite maps are not available, then the planning agencies may have a complete or partial file of subregional† zoning ordinances and maps. It is obviously desirable to find organizations, such as local or regional planning agencies, which have compiled much of the information sought. In all cases, begin by looking for data with regional planning commissions, then county agencies, with surveys of individual townships and municipalities used *only* as a last resort. In some metropolitan areas, especially those spanning state boundaries, more than one regional planning commission may be able to supply data. A few phone calls to all of these may save much time and effort. The only caution concerning such sources is the timeliness of the data. In some cases the data files are not updated frequently.

The large map mentioned earlier should be used to note what areas have composite maps. If the composite maps are recent, data collection for these areas is complete.

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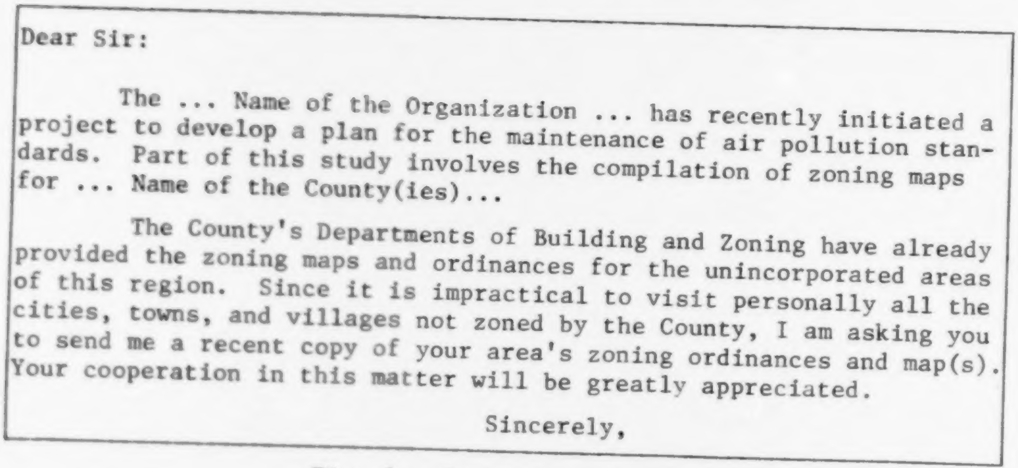
*A "composite" zoning map is defined here as a zoning map covering both incorporated and unincorporated areas.

**Also called planning commissions or boards. In some cases political subunits of county zoning boards are required to file an updated map with the board. These should be checked.

†Here defined as counties and their primary political and administrative subdivisions, including townships, cities, and villages.

For each area without composite maps, the survey team should compile a list of municipalities. This list should be checked against the municipality-zoning map files of the regional and county agencies. If the files are current, they should be used; if not, the municipalities should be contacted directly to obtain copies of their zoning ordinances and maps. Township maps may be handled in a similar manner.

A methodology for contacting individual municipalities was proven successful in the Chicago area zoning survey mentioned previously (Cohen et al., 1971). In that study, after all regional and county data sources were exhausted, a form letter (Fig. 8) was sent to each municipality from which zoning material was desired. A second list of "important" municipalities was developed. Important municipalities were those known to have heavy industry. After ten working days, all important municipalities that did not respond were telephoned. If copies of their maps were not available and a verbal description was not practical, a personal visit was planned. All five personal visits required in the Chicago study were made on the same day. During the personal visit, a street or township map was used to outline areas of interest.



Dear Sir:

The ... Name of the Organization ... has recently initiated a project to develop a plan for the maintenance of air pollution standards. Part of this study involves the compilation of zoning maps for ... Name of the County(ies)...

The County's Departments of Building and Zoning have already provided the zoning maps and ordinances for the unincorporated areas of this region. Since it is impractical to visit personally all the cities, towns, and villages not zoned by the County, I am asking you to send me a recent copy of your area's zoning ordinances and map(s). Your cooperation in this matter will be greatly appreciated.

Sincerely,

Fig. 8. Sample Form Letter

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STEP 2: PROCESS EDZ SOURCE DATA

SUMMARY

In Step 2, the data acquired in Step 1 are prepared for coding and keypunching. This is accomplished through two substeps:

Step 2A: Plot EDZ Source Grid Squares
Step 2B: Determine Zoning in Each Grid Square

Each land use class considered in the analysis located in each grid square is defined as an "EDZ source" for the dispersion model and linear program. The output of Step 2 is used in the location of EDZ receptors (Step 3) and the air quality dispersion model runs (Step 14).

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

Before beginning Step 2 you must have acquired the general regional map, UTM coordinates (see Appendix F if you are not using UTM coordinates), and zoning ordinances and maps described in Step 1 (see Fig. 9). The personnel, data, and hardware needed for Step 2 are shown in Table 3.

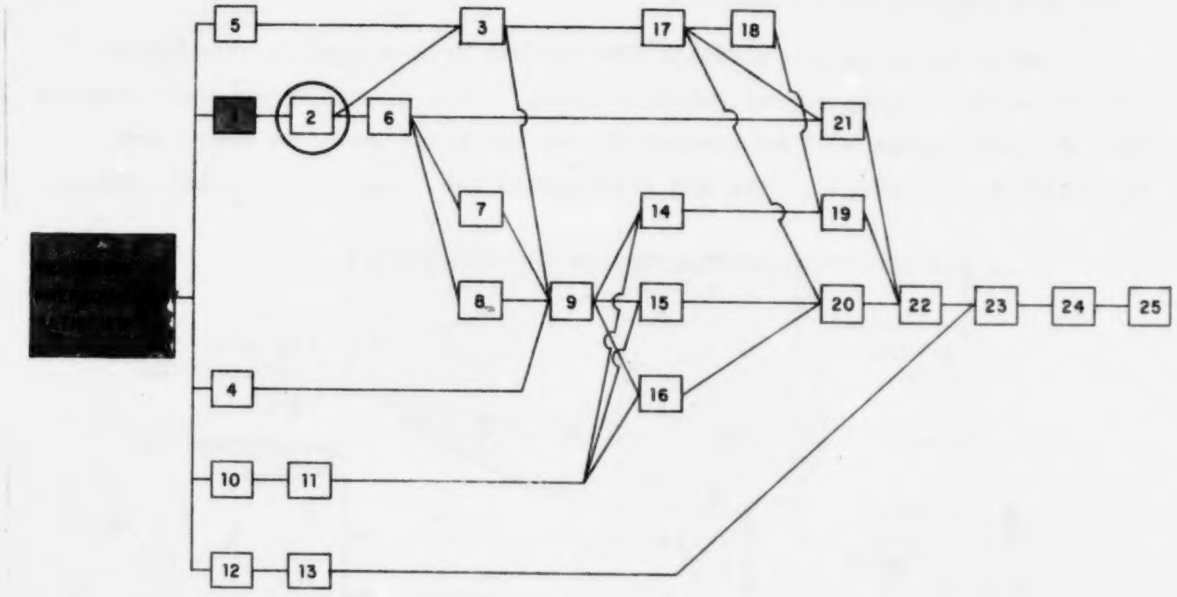


Fig. 9. Prerequisites for Step 2

Table 3. Resource Requirements for Step 2

Necessary Skills[a]	Necessary Data	Data Sources	Necessary Hardware
Cartographic Data Analysis Secretarial Possibly Land-Use Planning	Regional Map UTM Coordinates Zoning Maps	Step 1 Step 1 See Text	Cartographic Supplies

[a] First on list directs this step.

STEP 2A: PLOT EDZ SOURCE GRID SQUARES

Plot Grid Axes and 8 km x 8 km Grid Squares

Place transparent drawing material over the regional map prepared in Step 1 and locate a point that is at least 4 km west and 4 km south of the region's boundary and is also the intersection of UTM easting and northing grid lines. This point will be your *EDZ grid origin;* record its UTM coordinates and draw a pair of perpendicular lines through it (see Fig. 10). Now draw an 8 km grid system, as shown in Fig. 10. The 8 km grid system is recommended for most regions. If your region is smaller than 350 km^2, the use of 1 km^2 grid squares is recommended.

While it is rarely possible for the EDZ grid system to correspond exactly with the area source emission grids in the emission inventory used in Step 6, later steps will be simpler if the two grids share as many common coordinates as possible. The EDZ grid should not fragment or isolate major

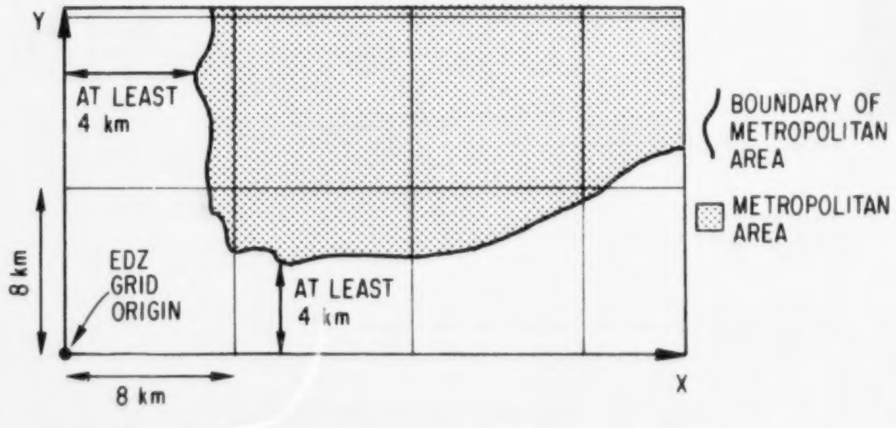


Fig. 10. Grid Axes and 8 km EDZ Grid System

population centers, heavy source concentrations, or physical barriers. Major political boundaries also should be considered.

Modify the 8 km Grid System

Increasing and decreasing the number and sizes of the grid squares in the 8 km system will provide a grid system that can be used for setting emission density limits. However, a better system may be derived taking into account specific characteristics of the region being studied. Therefore, you may wish to develop your own grid modification scheme. If so, the grid system must satisfy the following criteria:

- Areas with the highest population density or growth potential should be located in the smallest grid squares.
- The most sparsely settled or slowest growing areas should be in the largest grid squares.
- All grid square sizes *must be* integral multiples of each other (see Fig. 11). To ensure this feature, use square grids with side lengths equal to 1, 2, 4, and 8 km.

The problem in partitioning any area for EDZ source calculations is to choose the size of grid squares and their spatial arrangement. The number of grid squares used in the region dictates the cost of each computer run. The fewer grid squares, the less computer time used and the lower the cost. In addition, fewer grid squares will involve fewer hand calculations and, therefore, lower manpower costs. On the other hand, fewer grid squares (for a given land area) tend to decrease the dispersion model's precision.

A balance must be struck between cost and precision. A reasonable compromise is to have higher precision where population and pollution concentrations are highest, while less precision is tolerable elsewhere. This is the basis for the first two criteria listed above for modifying the 8 km grid square system. The third criterion is a direct requirement of the dispersion model suggested for use in the analysis (CDMQC).

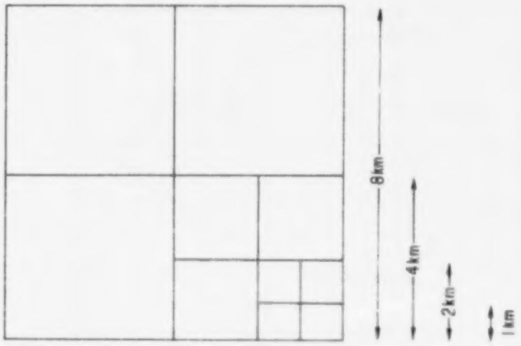
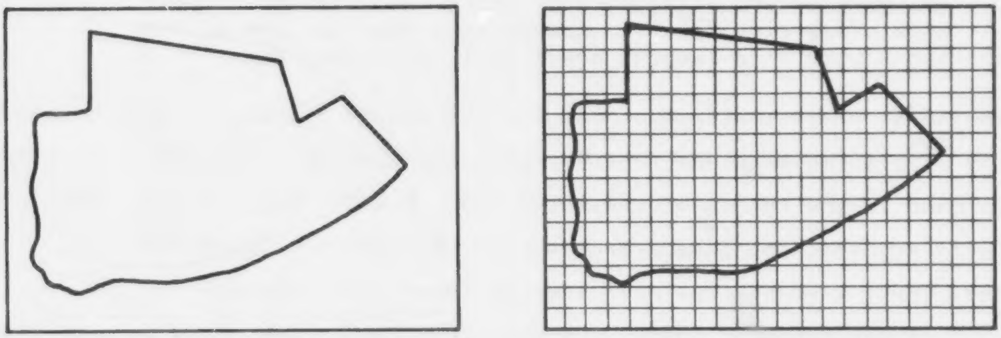


Fig. 11. Integral-Multiple Grid Square Sizes

As a rule of thumb the grid system used should contain about 350 grid squares, to attain adequate precision at a reasonable cost. Both aggregating or subdividing portions of the 8 km grid system may be required to obtain 350 grid squares. Simple procedures for carying out these tasks are presented below. Some trial and error will be required before a final grid system is obtained; this trial and error process should be conducted on drafting paper rather than on the acetate overlay of the regional map.

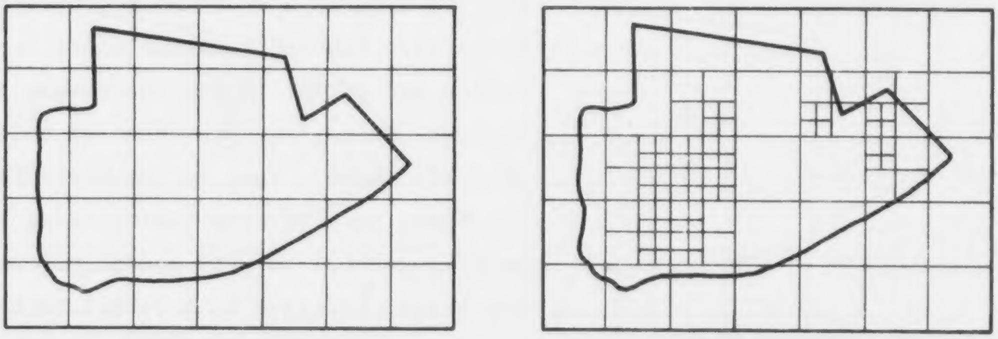
Figure 12 shows some examples of grid systems and their expected effects on the analysis.

Aggregating Grid Squares. If the region has more than 350 8 km grid squares then some squares should be combined; however, the number of grid squares larger than 64 km^2 should be kept to a minimum.



REGION TO BE GRIDDED

SMALL SQUARES:
HIGH PRECISION, HIGH COST



LARGE SQUARES:
LOW PRECISION, LOW COST

MIXED SQUARES:
REASONABLE PRECISION AND COST

Fig. 12. Alternate EDZ Grid Square Arrangements

A simple aggregation procedure is:

- Along the boundary of the region enlarge the grid squares to 16 km on a side provided the population densities in the areas are relatively low. Most likely these squares will be in unincorporated areas.
- The most densely populated areas or those of high growth potential should remain in grids no larger than 8 km on a side.
- If after this aggregation the number of grid squares still exceeds 350, some of the 16 km grids in the outlying areas may be aggregated into 32 km grid squares and neighboring 8 km grids may be aggregated into 16 km grids.
- Repeat the process until the number of grid squares is less than 350.

After increasing the size of some grid squares it may still be desirable to reduce the size of other squares in highly populated or growth areas. A procedure for reducing grid square sizes is presented below.

Subdividing Grid Squares. The 8 km grid squares may be subdivided to increase the accuracy of the analysis. The smallest grid square need not be less than 1 km on a side.

One simple subdivision approach is to leave 8 km grid squares in all unincorporated areas, and use 1 km grids in all incorporated areas. The main disadvantage to this system is that it may soon create more than 350 grid squares. The advantages are that it is fast, fairly simple, and treats all incorporated and unincorporated areas equally.

Another procedure for subdividing the 8 km squares is a 12-step procedure suggested by Benesh et al. (1977). A simplified version of his procedure, based solely on the population characteristics of the region, is that areas with existing or projected population densities:

- Greater than 2,000 persons/km^2 should be contained in grid squares no larger than 1 km^2.
- Between 1,000 and 2,000 persons/km^2 should be contained in grid squares no larger than 4 km^2.
- Between 200 and 1,000 persons/km^2 should be contained in grid squares no larger than 16 km^2.

It is recommended that population projections for EDZ be consistent with those used for 208, 201, and other planning efforts.

Plot Modified Grid System. After a final grid system is determined, it should be drawn onto the acetate overlay of the regional map by modifying the 8 x 8 km grid drawn earlier. A new piece of acetate may be needed if a number of 8 km grids were aggregated into larger grids. A completed grid system for the Louisville, Ky., area based on decision rules prepared by Benesh et al. (1977) is provided in Fig. 13.

Number the Grid Squares

Each square in the final grid system is to be given an identifying number. The numbering system used for the Louisville map in Fig. 13 is shown in Fig. 14. The numbering system is used only for identification purposes; therefore, the only requirement is that every square be assigned a number, starting with 1. It is suggested that the grid squares be numbered from left to right and top to bottom to facilitate locating them on the map.

List the Coordinates of Each Square's Southwest Corner

Using Worksheet 1* (see Fig. 15), record the UTM coordinates of the southwest corners of each grid square. The coordinates should be based on the coordinates of the intersections of the grid axes. If there is a UTM grid junction in your region, refer to Appendix E before filling out Worksheet 1.

STEP 2B: DETERMINE ZONING IN EACH GRID SQUARE

Although several standard land use zoning coding schemes have been developed, with few exceptions, none has gained national or even regional acceptance. You will probably have numerous zoning classes in your region.

It is theoretically pleasing to consider setting unique emission density limits for as many zoning categories as possible, but it is extremely expensive and practically impossible to consider every zoning class conceived of by every planning and zoning authority in a metropolitan area. The EDZ methodology requires that zoning classes between jurisdictions be standardized, and the number of zoning classes considered for analysis be kept to a minimum.

In Step 2B you will prepare simplified zoning maps that only show uniform regionwide zoning classes for use in setting emission density limits.

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*Full page, blank worksheets for your use are provided in Appendix J.

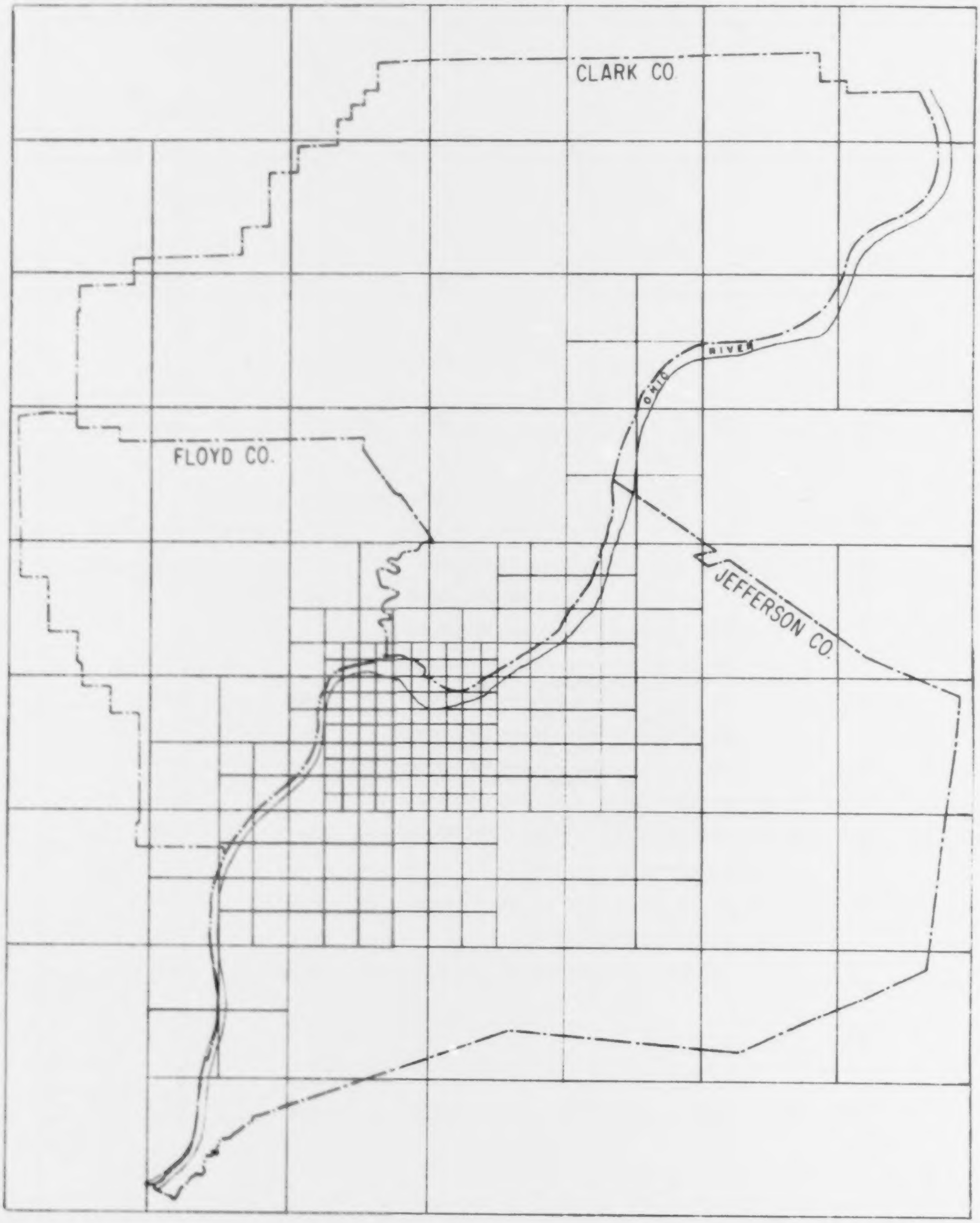

CLARK CO.
FLOYD CO.
OHIO RIVER
JEFFERSON CO.

Fig. 13. EDZ Grid System for Louisville, Ky. (from Benesh et al., 1977)

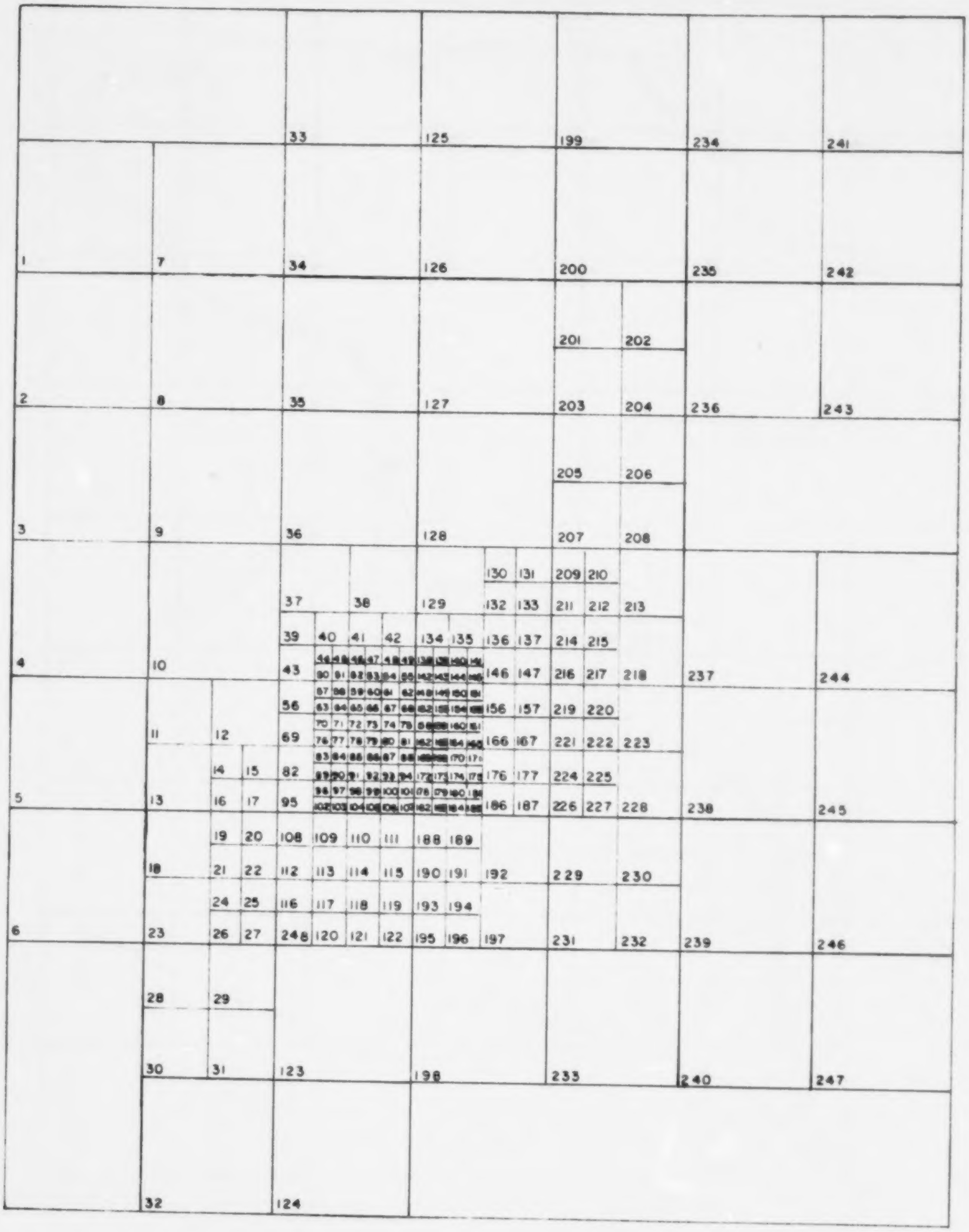

33 125 199 234 241
1 7 34 126 200 235 242
201 202
2 8 35 127 203 204 236 243
205 206
3 9 36 128 207 208
130 131 209 210
37 38 129 132 133 211 212 213
39 40 41 42 134 135 136 137 214 215
47
4 10 43 146 147 216 217 218 237 244
57 59 60 61 62 150
56 63 64 65 66 67 68 156 157 219 220
70 71 72 73 74 75 160 161
11 12 69 76 77 78 79 80 81 166 167 221 222 223
83 84 85 86 87 88 170
14 15 82 89 90 91 92 93 94 172 173 174 175 176 177 224 225
96 97 98 99 100 101 178 179 180
5 13 16 17 95 102 103 104 105 106 107 182 184 186 187 226 227 228 238 245
19 20 108 109 110 111 188 189
18 21 22 112 113 114 115 190 191 192 229 230
24 25 116 117 118 119 193 194
6 23 26 27 248 120 121 122 195 196 197 231 232 239 246
28 29
30 31 123 198 233 240 247
32 124

Fig. 14. Numbered EDZ Grid System for Louisville, Ky. (from Benesh et al., 1977)

WORKSHEET 1 (FOR STEP 2) FILLED OUT BY: ____________________ DATE __________ PG ___ OF ___
LIST OF SOUTHWEST CORNERS OF EDZ GRID SQUARES

EDZ GRID SQUARE NUMBER	NORMALIZED NORTHING IN km	NORMALIZED EASTING IN km
00024	714.0	4611.0
00025	715.0	4611.0
00026	714.0	4610.0
00027	715.0	4610.0
00028	716.0	4610.0
00029	718.0	4611.0
00030	719.0	4611.0
00031	718.0	4610.0

Fig. 15. Worksheet 1 Example

Create Uniform Regionwide Zoning Classes

By far the most important classes for EDZ are the heavily polluting industrial classes. Facilities located in commercial, residential, and open space areas usually have small emissions of sulfur dioxide (SO_2) and particulate matter; therefore, these light polluting classes should be simplified to one homogeneous class, called Class A (for Area Sources). The recommended classes to be used in simplifying zoning maps are:

A All residential, commercial, and open spaces except areas with very large structures (higher than 20 stories). Includes rights-of-way.

M1 Light Manufacturing District. Must have provisions for assembly, processing, fabrication, and storage plants. No raw materials should be processed into any of the following basic products: metals of any kind, glass, plastics, textiles, leather, paper, petroleum, chemicals, or food. Also no municipal incineration or motor-freight terminals are allowed in M1 districts. M1 includes areas with buildings more than 20 stories tall that were excluded from Class A.

M2 Medium Manufacturing District. Has the same restrictions as M1, but allows for municipal incineration and motor-freight terminals.

M3 Heavy Manufacturing District. No restrictions.

Many municipalities will have business districts that allow industrial processing activities. For the simplified maps, these districts would most likely be classified as M1. Similarly, a manufacturing district that allows food processing, but not the other exceptions, may still be classified as an M1 district.

One difficulty may arise while classifying manufacturing districts. Often stone or sand quarries and strip mines are classified as heavy manufacturing, and no distinction is made on the zoning map. *If* it is considered desirable to create a new class for these types of sources, additional information is needed to determine what sections of the region are quarries or mines.

Superimpose the regional EDZ grid system onto the zoning maps and then reclassify the zoning classes of all the various jurisdictions using the four classes suggested above (or a reasonable variation). Figures 16 and 17 show a grid square before and after reclassification and simplification. The maps resulting from reclassification will be called "simplified zoning maps" hereafter.

Estimate Areas of Each Land Use Class Within Each Grid Square (Designate EDZ Sources)

The simplified zoning maps must be analyzed to determine the area of each land use class falling into each of the grid squares mapped in Step 2A. Generally, finding the percentage of a grid square with a particular land use zoning classification will be easier than finding the area. Therefore, it will be assumed that percentages will be found first and then changed to areas (in hectares) for all the land use classes in each grid square.

There are a number of methods for finding the area covered by each class in each grid square; five of these are reviewed here. While any of the methods may be used, the simplest and one of the most accurate is the modified Monte Carlo method. This method has been tested and proven to be accurate to within 5% by Cohen, et al. (1971). All of the methods described below assume the grid squares developed in Step 2A have been superimposed upon the simplified zoning maps.

The Modified Monte Carlo Technique. This method, recommended for use in setting emission density limits, employs a dot pattern to generate percentages directly from the zoning map. A specially constructed stratified systematic unaligned (SSU) set of dots is laid on top of a grid square of the simplified zoning map. The number of dots lying within each zoning class is counted and then divided by the total number of dots in the grid square to give a percentage for each zoning class. A dot pattern consisting of 49 to 100 dots per EDZ grid square will generally work the best; the more dots per square, the greater the accuracy of the technique.

The recommended modified Monte Carlo procedure steps are:

1. Construct a simplified and gridded regional zoning map.
2. Construct SSU dot pattern on acetate, tracing paper, or some other transparent overlay material. This process is illustrated in Fig. 18.
3. Overlay SSU dots on each map grid square (see Fig. 19).
4. Count the number of dots falling into each zoning class (see Fig. 19).
5. Calculate the percentage of land in each zoning class for each grid square (see Fig. 19).
6. Tabulate the data using Worksheet 2 (see Fig. 20).

The five-step process presented in Fig. 18 is based on a discussion by Hadfield (1966). For a further description of SSU dot patterns see Berry (1962).

Alternate Methods for Estimating Areas. Five other methods that can be used in designating EDZ sources are described below.

A planimeter is an instrument that measures the area of a plane figure by tracing its boundary line. The most common types have a small rubber wheel that activates a counting device read by the operator. Planimeters can be extremely useful for measuring subsections of a metropolitan area, but their use is probably too time consuming for measuring every zoned parcel in every grid square.

The gravimetric technique uses mass (weight) as a measure of area. First, the gridded simplified zoning maps must be drawn onto special paper that, unlike regular paper, is of equal mass throughout its entire area.

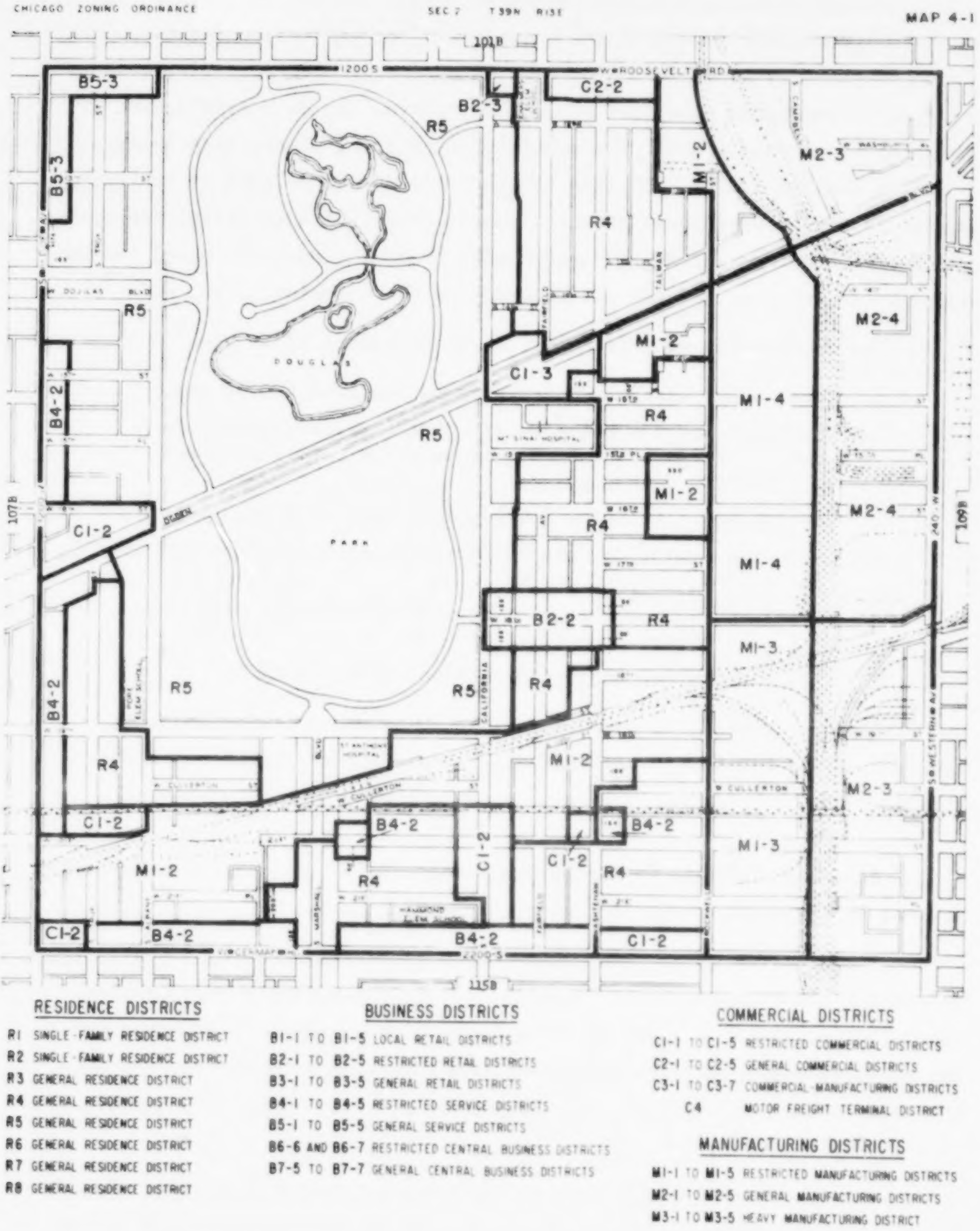

CHICAGO ZONING ORDINANCE
SEC 7 T39N R13E
MAP 4-I
101B
1200 S
W ROOSEVELT RD
B5-3
B2-3
C2-2
R5
M2-3
M1-2
R4
W DOUGLAS BLVD
DOUGLAS
PARK
OGDEN
M2-4
M1-2
C1-3
M1-4
R4
MT SINAI HOSPITAL
B4-2
R5
M1-2
M2-4
107B
C1-2
R4
M1-4
109B
B2-2
R4
M1-3
B4-2
R5
R5
R4
CALIFORNIA
ST ANTHONY HOSPITAL
M1-2
R4
W CULLERTON ST
M2-3
C1-2
B4-2
B4-2
M1-2
C1-2
C1-2
R4
M1-3
R4
HAMMOND ELEM SCHOOL
C1-2
B4-2
B4-2
C1-2
W CERMAK RD
2200 S
115B
S WESTERN AV
2400 W
RESIDENCE DISTRICTS
R1 SINGLE-FAMILY RESIDENCE DISTRICT
R2 SINGLE-FAMILY RESIDENCE DISTRICT
R3 GENERAL RESIDENCE DISTRICT
R4 GENERAL RESIDENCE DISTRICT
R5 GENERAL RESIDENCE DISTRICT
R6 GENERAL RESIDENCE DISTRICT
R7 GENERAL RESIDENCE DISTRICT
R8 GENERAL RESIDENCE DISTRICT
BUSINESS DISTRICTS
B1-1 TO B1-5 LOCAL RETAIL DISTRICTS
B2-1 TO B2-5 RESTRICTED RETAIL DISTRICTS
B3-1 TO B3-5 GENERAL RETAIL DISTRICTS
B4-1 TO B4-5 RESTRICTED SERVICE DISTRICTS
B5-1 TO B5-5 GENERAL SERVICE DISTRICTS
B6-6 AND B6-7 RESTRICTED CENTRAL BUSINESS DISTRICTS
B7-5 TO B7-7 GENERAL CENTRAL BUSINESS DISTRICTS
COMMERCIAL DISTRICTS
C1-1 TO C1-5 RESTRICTED COMMERCIAL DISTRICTS
C2-1 TO C2-5 GENERAL COMMERCIAL DISTRICTS
C3-1 TO C3-7 COMMERCIAL-MANUFACTURING DISTRICTS
C4 MOTOR FREIGHT TERMINAL DISTRICT
MANUFACTURING DISTRICTS
M1-1 TO M1-5 RESTRICTED MANUFACTURING DISTRICTS
M2-1 TO M2-5 GENERAL MANUFACTURING DISTRICTS
M3-1 TO M3-5 HEAVY MANUFACTURING DISTRICT

Fig. 16. Example of Complex Zoning (from City of Chicago Zoning Ordinance)

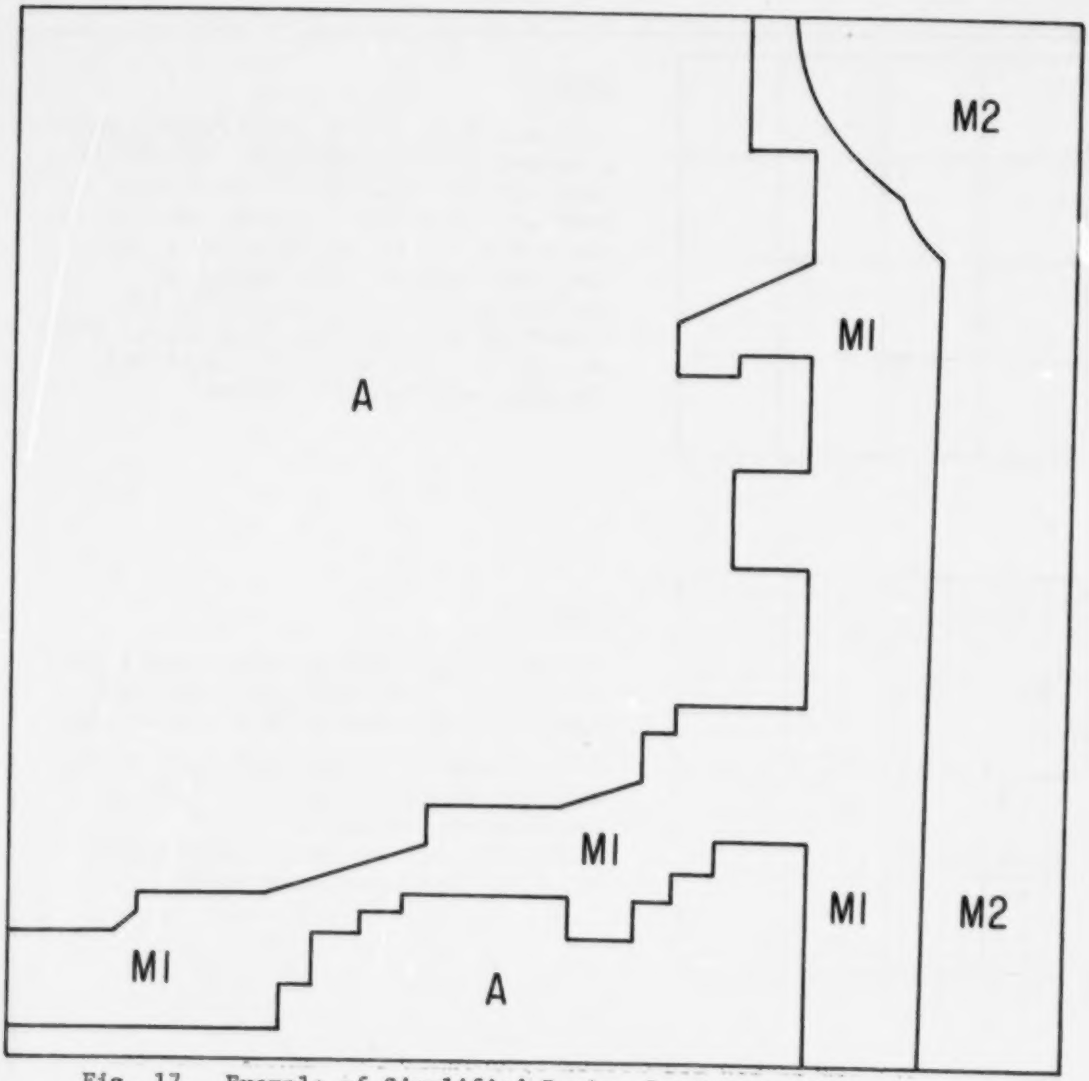
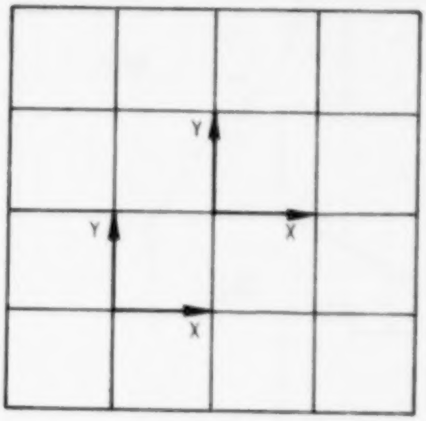


Fig. 17. Example of Simplified Zoning for Map in Fig. 16

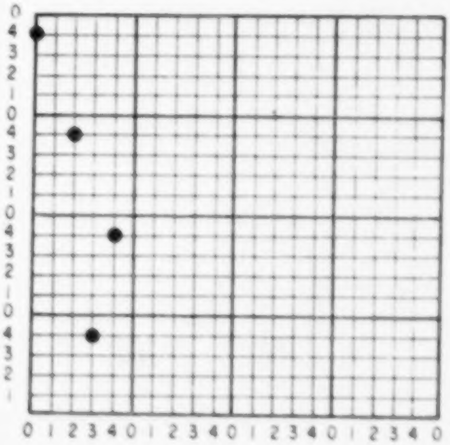
Each zoning class would be cut out of the paper, weighed on a highly sensitive balance, and the mass of the cut-outs compared to a "standard" piece of paper of known area. The area of the cut-outs is then determined by their mass relative to that of the standard. This technique is somewhat cumbersome.

Natural or contrived grids also may be superimposed on the map. Natural grids include grid pattern street layouts and grid utility lines. These may be used to estimate percent land area per zoning class if the grids are of known area. Since not all sections of a metropolitan area have grid street patterns, this method would have to be used in conjunction with another



STEP 1

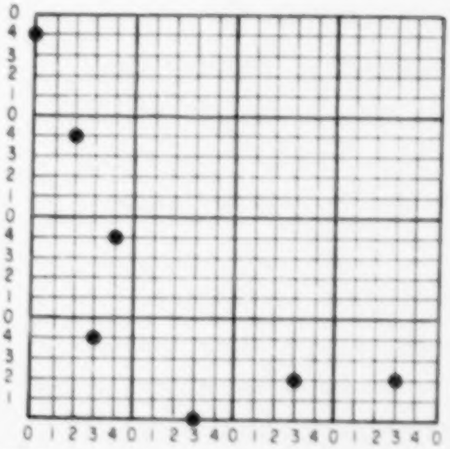
For each size of EDZ grid square, draw a square of the same size. Divide it into smaller squares of equal size. Each of these small squares has its own x and y axes, as shown here for two such squares. The number of smaller squares will determine the number of dots and the accuracy of the procedure. The more dots (squares) the more accurate the method.


0 4 3 2 1 0 4 3 2 1 0 4 3 2 1 0 4 3 2 1
0 1 2 3 4 0 1 2 3 4 0 1 2 3 4 0 1 2 3 4 0

STEP 2

For each small square, add x and y coordinates. Note that the lower left corner of each square is a new origin.

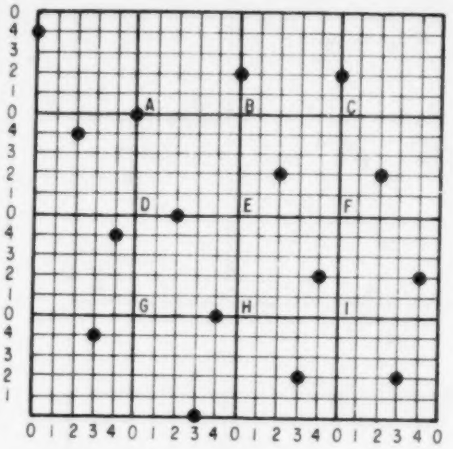
In all squares in the left-hand column add dots at points with the same y coordinates (chosen at random; 4 is used here) but random x coordinates (3, 4, 2, and 0 are used here).


0 4 3 2 1 0 4 3 2 1 0 4 3 2 1 0 4 3 2 1
0 1 2 3 4 0 1 2 3 4 0 1 2 3 4 0 1 2 3 4 0

STEP 3

In all remaining squares in the bottom row, add dots at points with the same x coordinates (value determined by the bottom left square; 3 in this example) but random y coordinates (0, 2, and 2 are used here).

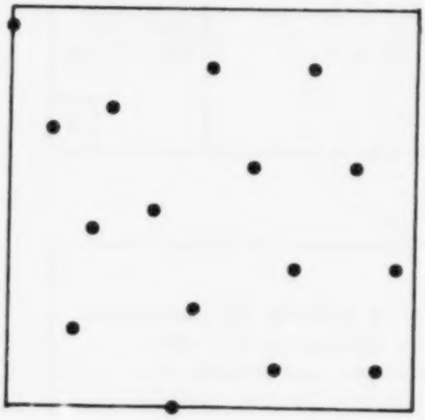
Fig. 18. Construction of an SSU Dot Pattern (continued on next page)



STEP 4

Place dots in all remaining squares. Each dot's x coordinate is taken from the left-hand column in the same row, and its y coordinate from the bottom row in the same column of squares. In this example the following points would be used:

A(0,0)	B(0,2)	C(0,2)
D(2,0)	E(2,2)	F(2,2)
G(4,0)	H(4,2)	I(4,2)



STEP 5

Remove all lines except the EDZ grid square boundary, either by erasing or by tracing the dots and boundary onto a piece of transparent paper. This is the completed SSU dot pattern. Its use is illustrated in Fig. 19.

Fig. 18. Construction of an SSU Dot Pattern (contd)

technique. Contrived grids, which are placed over the zoning maps, are transparent but have cells (rectangles, triangles, etc.) of known size on them. The amount of land in a zoning class falling into the square is totaled, with percent then calculated. Both of these grid methods suffer from the potential of being overloaded by too much data. The analyst trying to count city blocks or contrived squares will find the job much bigger than expected since coverage includes the entire metropolitan area.

Computer-assisted methods are summarily described by Chapin (1972). Two types are available to the agency fortunate enough to have the facilities. The first is a method where the analyst traces the outline of the zoned

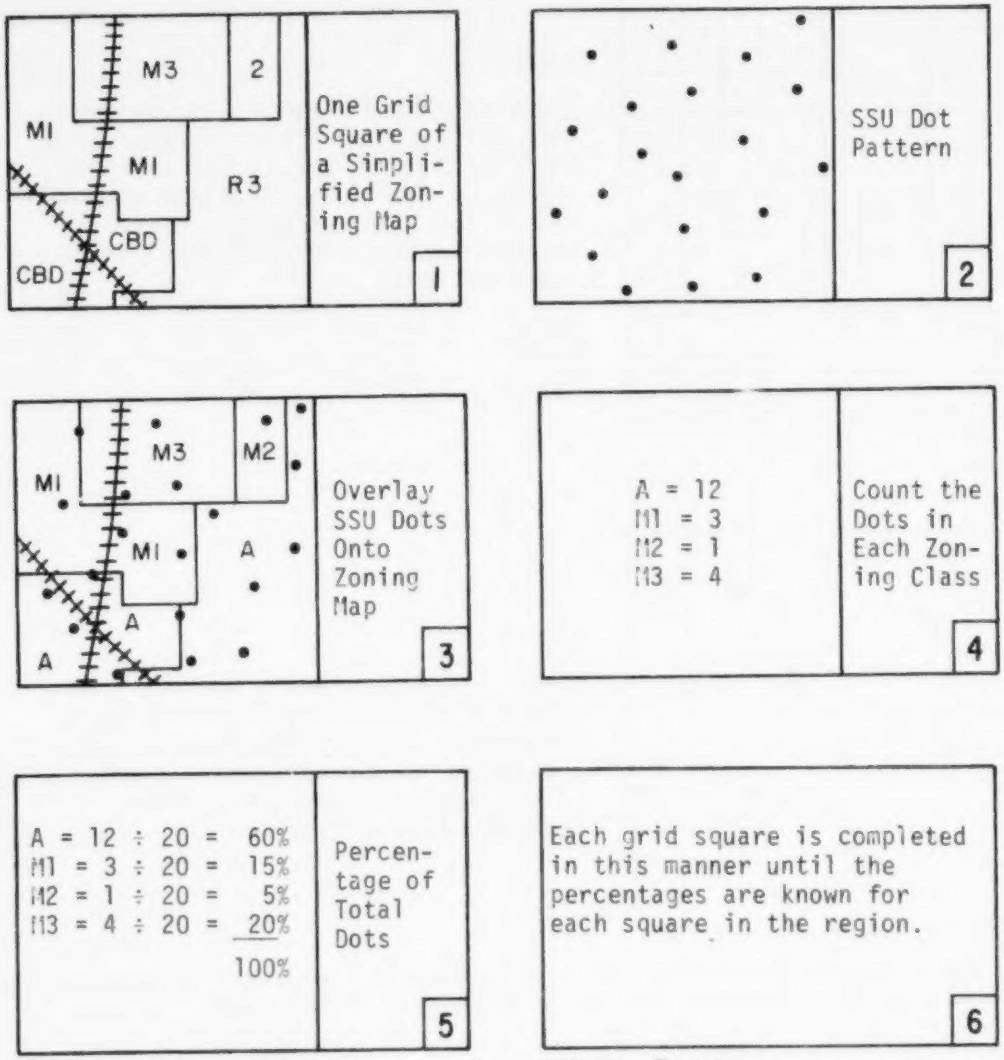

M3
2
MI
MI
R3
CBD
CBD
One Grid Square of a Simplified Zoning Map
1
SSU Dot Pattern
2
M3
M2
MI
MI
A
A
A
Overlay SSU Dots Onto Zoning Map
3
A = 12
M1 = 3
M2 = 1
M3 = 4
Count the Dots in Each Zoning Class
4
A = 12 ÷ 20 = 60%
M1 = 3 ÷ 20 = 15%
M2 = 1 ÷ 20 = 5%
M3 = 4 ÷ 20 = 20%
100%
Percentage of Total Dots
5
Each grid square is completed in this manner until the percentages are known for each square in the region.
6

Fig. 19. Use of an SSU Dot Pattern

area with a computer-linked stylus. The computer, functioning much like a sophisticated planimeter, computes the area of the outlined figures. The second method can be used only in areas with extensive land-use/zoning inventories that are punched on cards or stored in some other computer-compatible manner (disk-tape). Here, if either the area or dimensions of each zoned parcel are included in the data file, areas would be taken directly from the cards and aggregated by machine. If extensive computer-compatible surveys (with areas) are available, the regional zoning map would be virtually unnecessary. The fortunate planning agency may find such computer-compatible information in the city or county assessor's offices.

WORKSHEET 2 (FOR STEP 2) FILLED OUT BY: ____________ DATE ______ PG ___
PERCENTAGE AND AREA OF EDZ SOURCES OF ___

EDZ GRID SQUARE NUMBER	AREA OF GRID SQUARE (km^2)	SIMPLIFIED LAND USE CLASS							
		A		M1		M2		M3	
		%	AREA: % x GRID SQUARE AREA (km^2)	%	AREA: % x GRID SQUARE AREA (km^2)	%	AREA: % x GRID SQUARE AREA (km^2)	%	AREA: % x GRID SQUARE AREA (km^2)
00024	1	100	1		—		—		—
00025	1	100	1		—		—		—
00026	1	100	1		—		—		—
00027	1	100	1		—		—		—
00028	4	100	4		—		—		—
00029	1	100	1		—		—		—
00030	1	100	1		—		—		—
00031	1	68.75	0.6875		—		—	31.25	0.3125 0001
00032	1	100	1		—		—		—
00033	4	100	4		—		—		—
00034	4	73.44	2.9376		—	21.88	0.8752 0002	4.69	0.1872 0003
00035	4	87.50	3.5000	3.12	0.1248 0004		—	9.38	0.3744 0005
00036	1	81.25	0.8125	18.75	0.1875 0006		—		—
00037	1	100	1		—		—		—
00038	1	100	1		—		—		—
00039	1	100	1		—		—		—

Fig. 20. Worksheet 2 Example

"Eyeballing" is unquestionably the simplest, but unfortunately the most inaccurate method for determining area. Studies (Robinson and Sale, 1969) have shown that in judging the area of circles, people average 80% accuracy, which would lead to questionable results for EDZ purposes. This method is not recommended.

Number EDZ Sources

Worksheet 2, shown in Fig. 20, is for use in recording the percent and area of each land use class in each grid square. Each EDZ source must be given an identifying number. The numbers are to be written directly on the worksheets. No Class A EDZ sources are to be numbered if they are to be exempt from EDZ.* If there are no hectares of land in a particular land use class in a grid square, that class within that grid square is *not* to be numbered.

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*See discussion of exempt sources in the Introduction and Step 7.

STEP 3: SELECT EDZ RECEPTOR LOCATIONS

SUMMARY

Locations at which the dispersion model will estimate air quality are selected in this step. These locations are referred to as EDZ receptors. The following substeps are involved in selecting EDZ receptor locations:

Step 3A: Determine the Selection Technique to be Used
Step 3B: Locate Receptor Points
Step 3C: Record Receptor Locations

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

The gridded map prepared in Step 2 and the locations of monitoring stations obtained in Step 5 are used to select EDZ receptor locations. The position of Step 3 in the EDZ methodology is shown in Fig. 21. The personnel, data, and hardware needed for Step 3 are listed in Table 4.

STEP 3A: DETERMINE THE SELECTION TECHNIQUE TO BE USED

A method must be selected for use in locating receptor points. Since the cost and accuracy of the analysis increases as the number of receptor

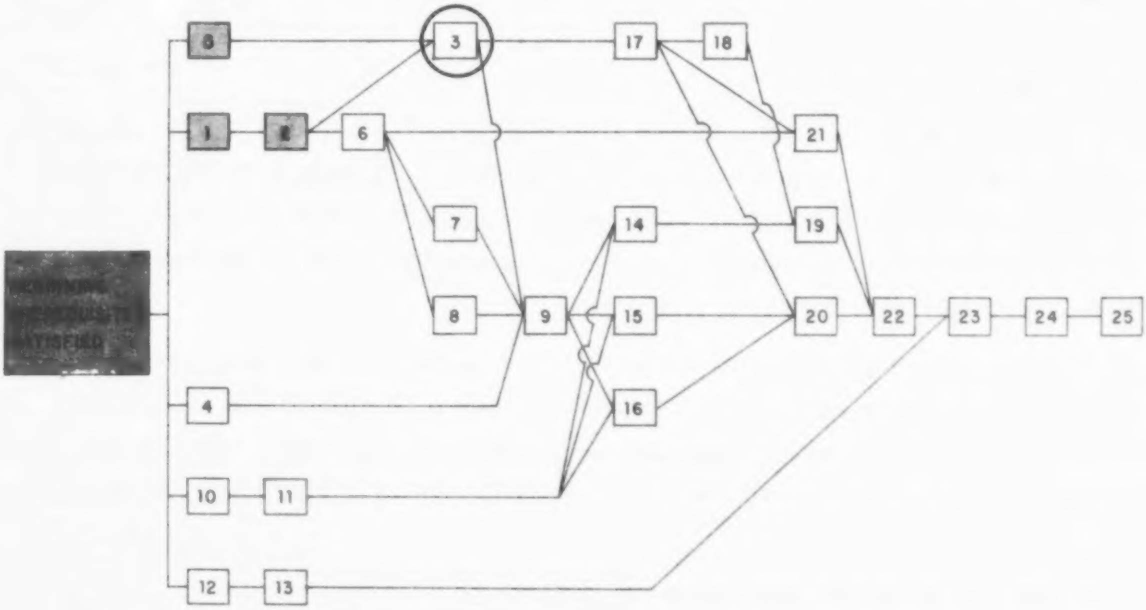

Fig. 21. Prerequisites for Step 3

Table 4. Resource Requirements for Step 3

Necessary Skills[a]	Necessary Data	Data Sources	Necessary Hardware
Land Use Planning Possibly: Cartographic Data Analysis	Gridded Regional Map	Step 2	Cartographic Materials

[a] First on list directs this step.

points increases, a trade-off between cost and accuracy similar to the one found in the regional gridding procedure (see Step 2) must be made. No more than 200 receptor points for the entire region can be used per run of CDMQC.* The receptor locations should satisfy the following criteria:

- Areas of high population densities or growth potential should have the highest concentration of receptors.
- Some receptor points should be located just outside the boundary of and extend all the way around the region.
- The locations of monitoring stations may be defined as EDZ receptor locations.**

A number of alternative methods for selecting receptor points are discussed below.

Center/Boundary Technique

The simplest way to locate receptor points is to place one in the geographic center of each grid square (see Fig. 22). In each grid square that includes the region's boundary line, and is 16 km on a side or larger, an additional receptor is located within the square but outside the regional boundary (see Fig. 23).

The advantage of this system is its simplicity. The disadvantages are: (1) the number of receptors to be considered in the linear program becomes very large, therefore increasing the run time and cost; and (2) the receptors may not be located in the most advantageous positions. If the

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*If you are using the AQDM dispersion model, see Apendix G, Sec. 4. If more than 200 receptor points are needed and you are using CDMQC, see Appendix I.

**If you are using AQDM, see Appendix G, Secs. 4 and 5.

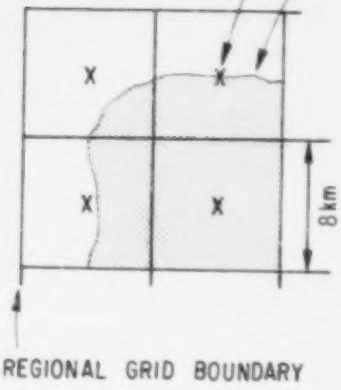
8km
REGIONAL GRID BOUNDARY

Fig. 22. Receptor Placement in 8 km EDZ Grid Squares Using Center/Boundary Technique

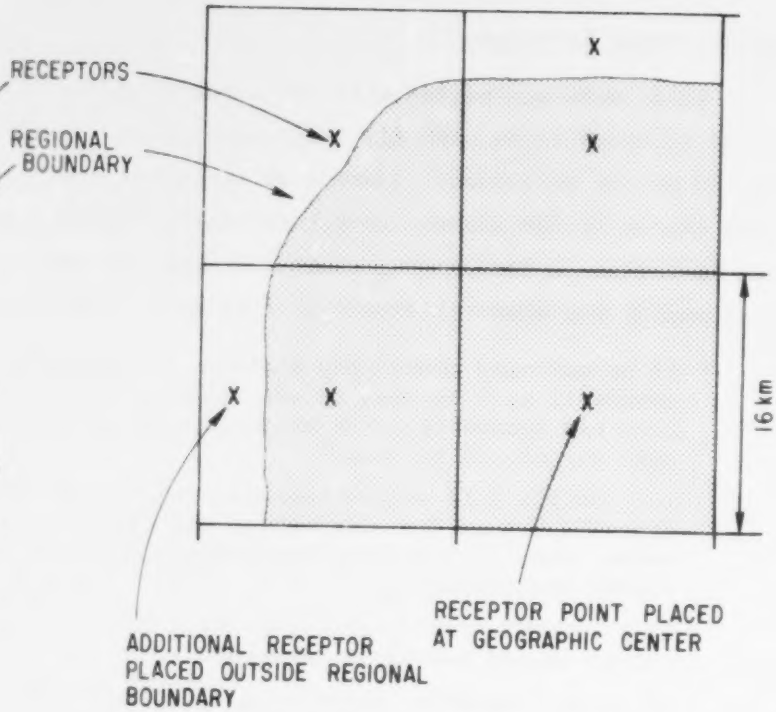
RECEPTORS
REGIONAL BOUNDARY
16 km
ADDITIONAL RECEPTOR PLACED OUTSIDE REGIONAL BOUNDARY
RECEPTOR POINT PLACED AT GEOGRAPHIC CENTER

Fig. 23. Receptor Placement in 16 km EDZ Grid Squares Using Center/Boundary Technique

accuracy of the dispersion model is going to be checked against actual measured data, the receptor points and the location of the actual monitoring stations should be the same. In addition, some locations, such as nursing homes, may have features that make them more susceptible to air pollution damage than others and receptors should be placed in the more sensitive areas. The center/boundary technique makes no allowance for special conditions other than the refinements produced by variable-sized grid squares.

Uniform Receptor Grid

Another simple technique is to superimpose a uniform grid of receptors over the region such that some receptors lie beyond the regional boundaries and the entire region is covered by receptors. By changing the density of the receptor grid, the number of receptors can be controlled; however, as with the center/boundary approach the receptors may not be in the most advantageous locations.

Activity-Based Technique

This technique begins with the assumption that receptors should be located in those areas with (1) large populations or (2) populations easily affected by air pollution. Instead of requiring that each receptor be placed in the center of the square, this technique provides a number of decision rules to follow in determining whether a receptor should be placed in a square and if so, where it should be located. These decision rules are:

- If an existing monitoring station is located within the square it will be used as the receptor point. If more than one monitoring station is located in a grid, then only one should be used.*
- If a single grid square contains areas with different classifications for significant deterioration requirements, then at least one receptor point is to be located within each area.
- If the population density exceeds 3,000/km^2, then the square should contain a receptor.
- If large hospitals, schools, nursing homes, etc. are considered places where air quality should be known, they should receive receptor points. However, the large number of such institutions may lead to too many receptor points if care is not exercised.
- If none of the above four rules apply to a square, locate a receptor in the center of the square.
- As with the center/boundary technique, receptors are to be placed just outside the regional boundary.

Politically Derived Receptor Locations

Here, every political jurisdiction would receive a receptor point placed at its population centroid. Receptors are also placed just outside the regional boundary as done in the center/boundary technique.

STEP 3B: LOCATE RECEPTOR POINTS

Once the decision has been made on how to select receptors, the next step is to map them onto the gridded regional map. Each receptor must be numbered. This mapping will allow you to see the distribution of points and their geographic, political, and population density relationships.

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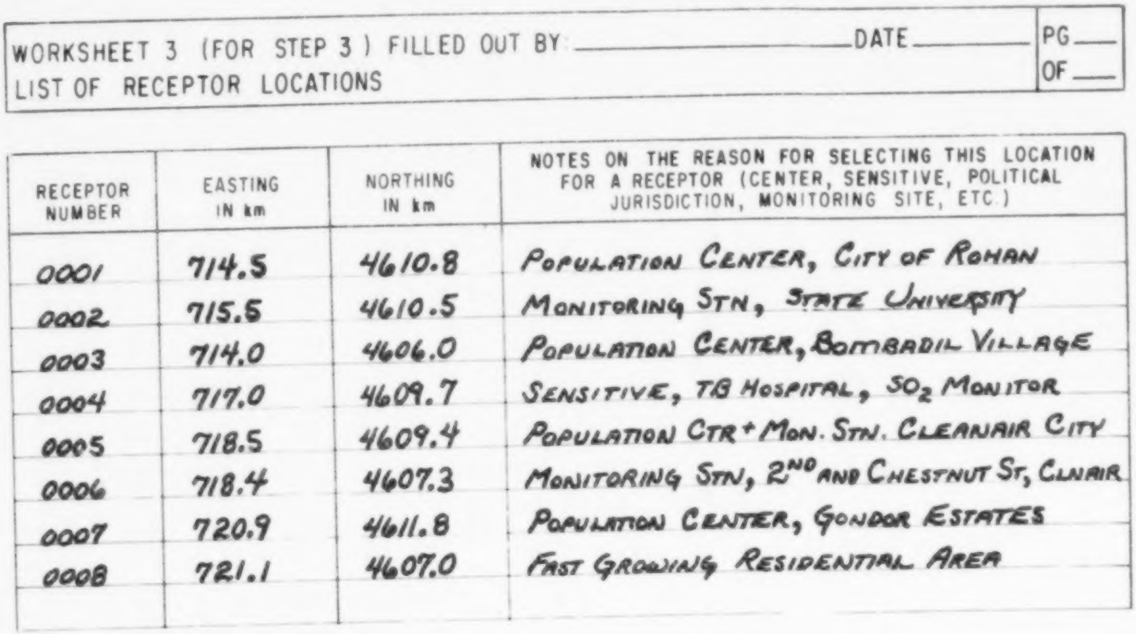
*If you are using AQDM, see Appendix G, Sec. 5.

STEP 3C: RECORD RECEPTOR LOCATIONS

The UTM coordinates of each mapped receptor point are to be recorded (in kilometers rather than meters) on Worksheet 3 (see Fig. 24).* The coordinates can easily be determined from the coordinates of the southwest corner of each grid square.



WORKSHEET 3 (FOR STEP 3) FILLED OUT BY ____________ DATE ________ PG ___
LIST OF RECEPTOR LOCATIONS OF ___

RECEPTOR NUMBER	EASTING IN km	NORTHING IN km	NOTES ON THE REASON FOR SELECTING THIS LOCATION FOR A RECEPTOR (CENTER, SENSITIVE, POLITICAL JURISDICTION, MONITORING SITE, ETC.)
0001	714.5	4610.8	Population Center, City of Rohan
0002	715.5	4610.5	Monitoring Stn, State University
0003	714.0	4606.0	Population Center, Bombadil Village
0004	717.0	4609.7	Sensitive, TB Hospital, SO_2 Monitor
0005	718.5	4609.4	Population Ctr + Mon. Stn. Cleanair City
0006	718.4	4607.3	Monitoring Stn, 2nd and Chestnut St, Clnair
0007	720.9	4611.8	Population Center, Gondor Estates
0008	721.1	4607.0	Fast Growing Residential Area

Fig. 24. Worksheet 3 Example

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*Full page, blank worksheets for your use are provided in Appendix J.

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STEP 4: ACQUIRE AND PROCESS METEOROLOGICAL DATA

SUMMARY

In Step 4 you will collect the meteorological data required for the dispersion modeling and then put it into the proper form for later coding and keypunching. Two substeps are involved:

Step 4A: Acquire Meteorological Data
Step 4B: Process Meteorological Data

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

Only the prerequisites set forth in the Introduction must be fulfilled, as shown in Fig. 25. The personnel and data requirements are shown in Table 5.

STEP 4A: ACQUIRE METEOROLOGICAL DATA

Three types of regional meteorological data are needed for dispersion modeling:*

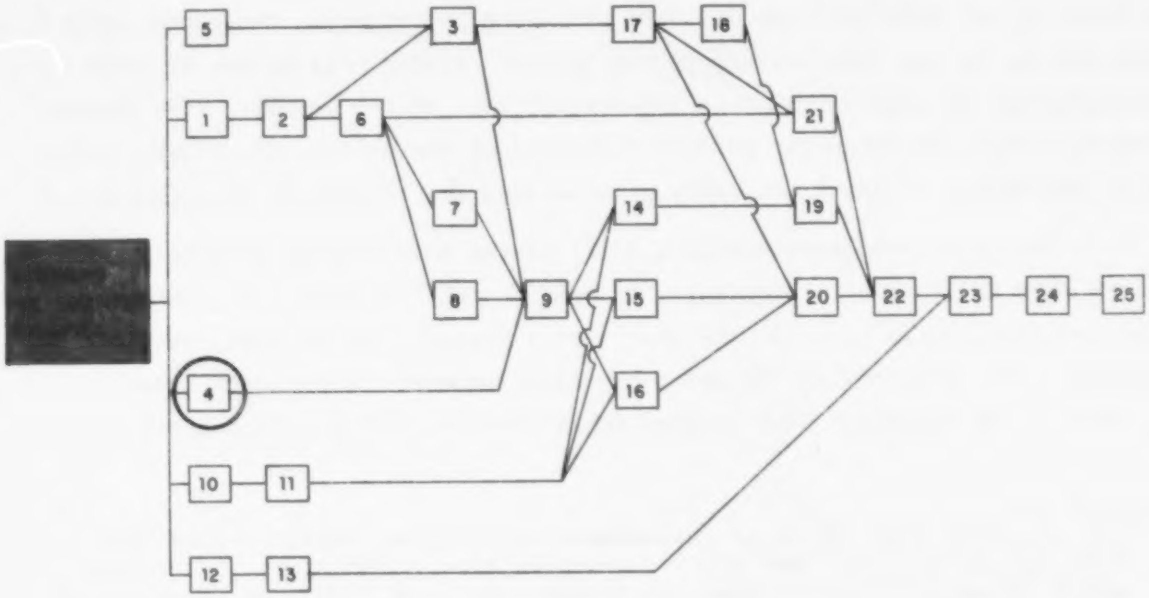

Fig. 25. Prerequisites for Step 4

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*If you are using AQDM, see Appendix G, Sec. 7.

Table 5. Resource Requirements for Step 4

Necessary Skills[a]	Necessary Data	Data Sources	Necessary Hardware
Data Analysis Secretarial	Meteorological Data	See Text[b]	None

[a] First on list directs this step.

[b] If you are using AQDM, see Appendix G, Sec. 7.

- Mean annual atmospheric temperature (°C)
- Mixing heights (meters). Both mean annual afternoon mixing heights and mean annual nocturnal (or morning) mixing heights are needed.
- Joint frequency function (% of time/situation); (1) for one year which matches the monitoring station data, and (2) a 5- or 10-year average for the region.

The mean atmospheric temperature may be collected from an almanac, the National Climatic Center, or virtually any source of weather information.

The mixing heights are a measure of the distance from the ground to a layer of air that will not mix very well with pollutants. The layer represents a cap on how high pollutants can travel. Mixing heights may be estimated using the maps supplied in Holzworth, G.C., *Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States*, U.S. EPA Report AP-101 (Jan. 1972). These maps are reproduced in Appendix D.*

The joint frequency function (JFF) is the most complex meteorological input used in dispersion modeling. It consists of 576 weather situations derived from hourly observations made over a year.** The National Weather Service calculates the JFF by using Day-Night versions of the STAR computer program. The Day-Night STAR program takes three variables - wind speed class, wind direction sector, and stability class - and calculates the percentage of time that all three coincide (see Table 6).

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*The Holzworth book, which is recommended only if you desire more information, may be ordered from: Library Services Branch, Mail Drop 35, Environmental Protection Agency, Research Triangle Park, NC 27711, at no charge if available; or at a nominal charge from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

**If you are using AQDM, see Appendix G, Sec. 7.

The Day-Night STAR program provides the JFF in the exact form needed for CDMQC, the dispersion model recommended for use in setting emission density limits. No format changes are required. Card output for the Day-Night STAR program for your metropolitan area may be obtained from: Tape Division, National Climatic Center, Federal Building, Asheville, NC 28801 (Telephone 919-672-0203).

You should call the Tape Division to be sure the Day-Night STAR program data are available for your region and to make payment arrangements. The NCC charges a nominal fee to cover its costs. In many cases, data for more than one year are available. The choice of year is left to your discretion, but for the calibration run of the dispersion model, the year of the

Table 6. The Variables Comprising the Joint Frequency Function

Wind Speed		
	Speed Interval	
Class	(knots)	(mph)
1	0- 3	0- 3.45
2	4- 6	4.6 - 6.9
3	7-10	8.05-11.5
4	11-16	12.65-18.4
5	17-21	19.55-24.15
6	>21	>24.15

Stability	
Class[a]	Explanation
1	1 is the most stable; 6 is the least stable. Stability is determined by incoming solar radiation (determined by cloud cover and height, and solar altitude) and wind speed.
2	
3	
4	
5	
6	

Wind Direction Sectors	
1	N
2	NNE
3	NE
4	ENE
5	E
6	ESE
7	SE
8	SSE
9	S
10	SSW
11	SW
12	WSW
13	W
14	WNW
15	NW
16	NNW

[a] If you are using AQDM, see Appendix G, Sec. 7.

JFF and the year of the monitoring station data should be the same. The National Climatic Center can supply 5- to 10-year average data for the Day-Night STAR program; this long-term average data should be used in the air quality and right-hand-side dispersion model runs. If the long-term average is unavailable, use single year data.

STEP 4B: PROCESS METEOROLOGICAL DATA

Step 4B assures that English-to-metric and metric-to-metric conversions have been completed for: mean annual atmospheric temperature, mean annual mixing heights, and the joint frequency function.*

The mean annual atmospheric temperature must be in degrees Celsius (°C);* a conversion formula for changing Fahrenheit to Celsius is provided in Appendix C. The figure should be rounded to two decimal places and recorded on Worksheet 4 (see Fig. 26).**

The mean annual mixing heights must be in meters (not kilometers) and estimated to the nearest meter. Record the value on Worksheet 4.

The joint frequency function data should be received on cards (or tape) and in the correct format for CDMQC. No changes will be necessary. If the JFF is not available on cards, the card format is shown in Step 9 for converting printed output to the proper card format.

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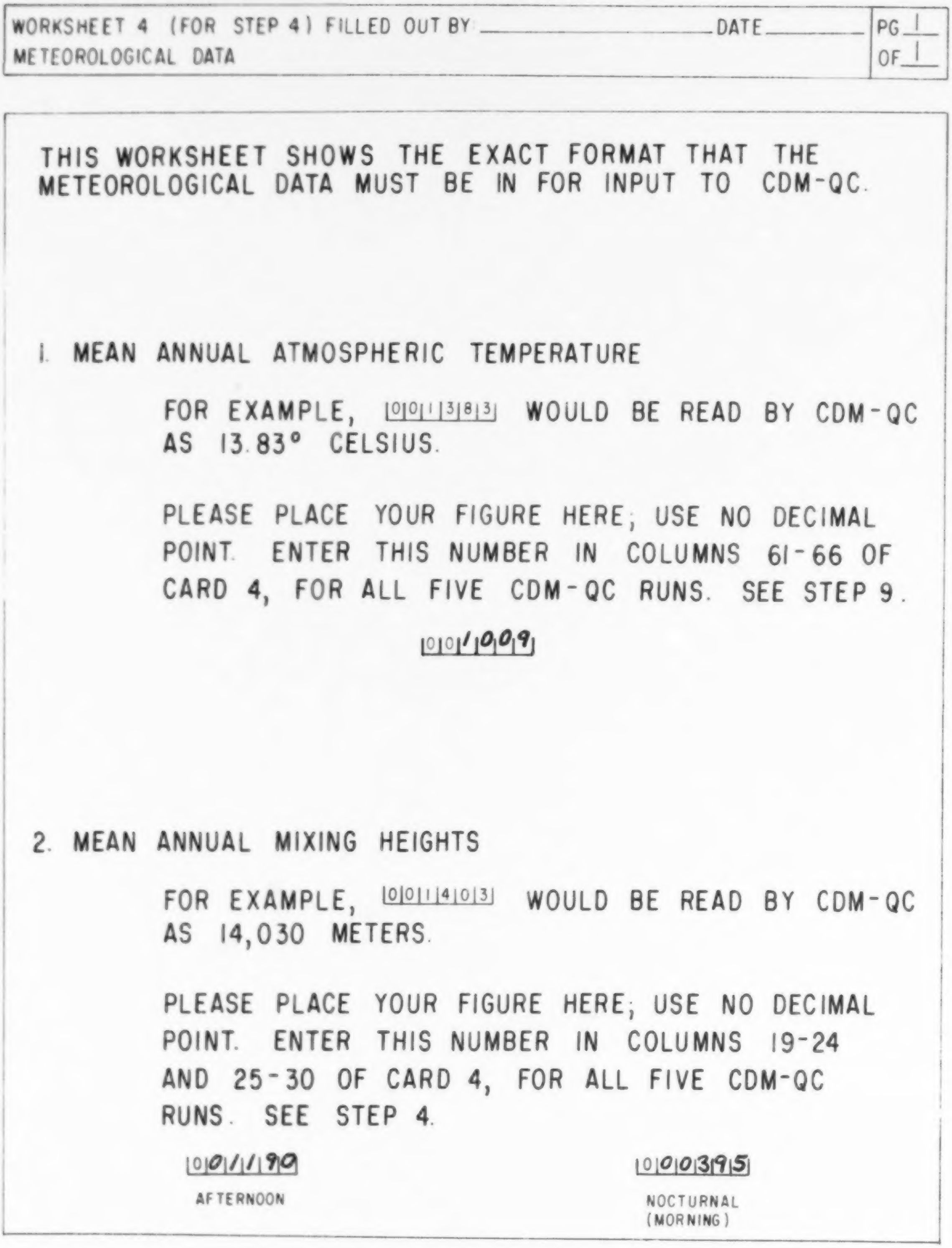
*If you are using AQDM, see Appendix G, Sec. 7.

**Full page, blank worksheets for your use are provided in Appendix J.



WORKSHEET 4 (FOR STEP 4) FILLED OUT BY ____________ DATE ________ PG 1
METEOROLOGICAL DATA OF 1

THIS WORKSHEET SHOWS THE EXACT FORMAT THAT THE METEOROLOGICAL DATA MUST BE IN FOR INPUT TO CDM-QC.

1. MEAN ANNUAL ATMOSPHERIC TEMPERATURE

FOR EXAMPLE, 001383 WOULD BE READ BY CDM-QC AS 13.83° CELSIUS.

PLEASE PLACE YOUR FIGURE HERE; USE NO DECIMAL POINT. ENTER THIS NUMBER IN COLUMNS 61-66 OF CARD 4, FOR ALL FIVE CDM-QC RUNS. SEE STEP 9.

001009

2. MEAN ANNUAL MIXING HEIGHTS

FOR EXAMPLE, 001403 WOULD BE READ BY CDM-QC AS 14,030 METERS.

PLEASE PLACE YOUR FIGURE HERE; USE NO DECIMAL POINT. ENTER THIS NUMBER IN COLUMNS 19-24 AND 25-30 OF CARD 4, FOR ALL FIVE CDM-QC RUNS. SEE STEP 4.

001190
AFTERNOON

000395
NOCTURNAL
(MORNING)

Fig. 26. Worksheet 4 Example

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STEP 5: ACQUIRE AND PROCESS MONITORING STATION DATA

SUMMARY

In Step 5, you will obtain (Step 5A) and process (Step 5B) data from the region's monitoring stations that are needed for the calibration run of the dispersion model (Step 15). Monitoring station locations may also be used as EDZ receptors in Step 3.

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

Only the prerequisites outlined in the Introduction must be fulfilled, as illustrated in Fig. 27. Minimal resources are required for this step; see Table 7.

STEP 5A: ACQUIRE MONITORING STATION DATA

Actual air pollutant concentrations, as measured at monitoring stations, form the basis for the calibration run of the dispersion model. The concentrations simulated by the dispersion model are checked against the calibration data to bring the computed values more in line with reality.

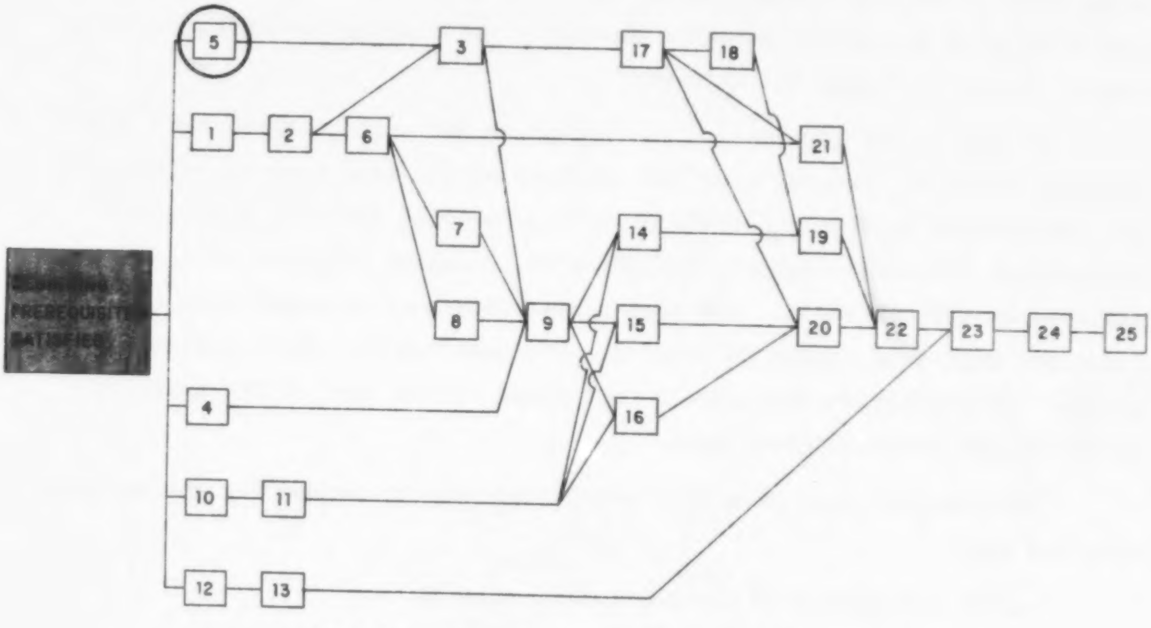

Fig. 27. Prerequisites for Step 5

Table 7. Resource Requirements for Step 5

Necessary Skills[a]	Necessary Data	Necessary Hardware
Data Analysis Secretarial	None	None

[a]First on list direct this step.

The completeness of monitoring station data will vary from region to region due to availability of local or state-operated monitors. You should check with both state and local agencies for data.

The most uniform source of information is the U.S. EPA's Storage and Retrieval of Aerometric Data (SAROAD) system. Each year, the EPA publishes two reports containing the monitoring station data needed for EDZ: *Directory of Air Quality Monitoring Sites Active in 19__*, and *Air Quality Data 19__, Annual Statistics*. Both are published about nine months after the year in which the data are collected. Single copies of these publications may be obtained free of charge from: Library Services Branch, Mail Drop 35, Environmental Protection Agency, Research Triangle Park, NC 27711. A telephone call to the EPA Library at 919-541-2777 (Research Triangle Park, NC) can be helpful in quickly ordering the books and finding out if they are in stock. Allow 7-10 days for delivery.

If the latest editions of the books are not available and the latest data are required, contact your EPA regional office (see Fig. 30 on page 75) or: Monitoring Data and Analysis Division, National Air Data Branch, Environmental Protection Agency, Mail Drop 14, Research Triangle Park, NC 27711 (telephone: 919-541-5395). The more recent data must be taken from computer files and will take longer to process. You must ask for the exact data desired. The monitoring data should correspond to the year of the emission inventory and meteorological data.

The specific data from each monitoring station needed for the calibration run are:

- UTM coordinates of the monitoring station.
- Measured concentration of SO_2 in $\mu g/m^3$ (annual arithmetic mean).

- Measured concentration of particulates in μg/m^3 (annual arithmetic mean).
- Standard geometric deviation for particulate concentrations.

STEP 5: PROCESS MONITORING STATION DATA

Worksheet 5, shown in Fig. 28, is recommended for use in tabulating the data.* The data may require two changes before input to the dispersion model. English units must be converted to metric equivalents and UTM coordinates may require normalization. The unit conversions are:

- UTM coordinates must be expressed in kilometers.
- Concentrations (annual arithmetic means) for SO_2 and particulates must be expressed in micrograms/cubic meter.
- Annual standard geometric deviation for particulates must be expressed in micrograms/cubic meter.

WORKSHEET 5 (FOR STEP 5) FILLED OUT BY:_______________ DATE _______ PG___
MONITORING STATION DATA OF___

NAME OF STATION	STATION I.D. NUMBER (FOUR DIGITS)*	UTM LOCATION (NORMALIZED) IN km TO ONE DECIMAL PLACE XXXX.X		MEASURED CONCENTRATIONS, ANNUAL ARITHMETIC MEAN (μg/m^3)		STANDARD 24-HR GEOMETRIC DEVIATIONS (μg/m^3)	
		EASTING	NORTHING	SO_2	PART	SO_2	PART
STATE UNIV.	0100	715.5	4610.5	39.0	62.0	4.02	1.56
TB HOSPITAL	0200	717.0	4609.7	48.0	—	3.01	—
CLEANAIR	0300	718.5	4609.4	43.5	74.0	4.37	1.51
2ND + CHESTNUT	0400	718.4	4607.3	35.0	61.0	1.52	2.14
FAST GROW 1	0500	721.1	4607.0	30.0	61.0	2.97	1.50
LORIÉN HOSP	0600	723.7	46[illegible]0.9	42.0	77.0	3.50	1.86

Fig. 28. Worksheet 5 Example

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*Full page, blank worksheets for your use are provided in Appendix J.

- Four-digit identifying numbers must be attached to each station to identify the data. The monitoring station identifying numbers may be changed in Step 3 if monitoring sites are used as EDZ receptors.

Metric-English conversions are provided in Appendix C. Worksheet 5, shown in Fig. 28, is recommended for use in tabulating the data. If your region includes a UTM grid junction, see Appendix E. If you are not using UTM coordinates, see Appendix F.

STEP 6: ACQUIRE AND PROCESS EMISSION INVENTORY DATA

SUMMARY

In Step 6 data needed for the dispersion model are acquired from state or federal emission inventories and processed. Four substeps are involved:

Step 6A: Acquire Point Source Data
Step 6B: Acquire Area Source Data
Step 6C: Make English-to-Metric Conversions for Emission Inventory
Step 6D: Prepare Emission Inventory Data for Use in Step 21

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

For Steps 6A-6C, only the beginning prerequisites need be fulfilled; data from Steps 1 and 2 are needed for Step 6D. The necessary personnel and data are shown in Table 8.

STEP 6A: ACQUIRE POINT SOURCE DATA

CDMQC, the dispersion model recommended for use in EDZ, requires the following information on each point source in the region:*

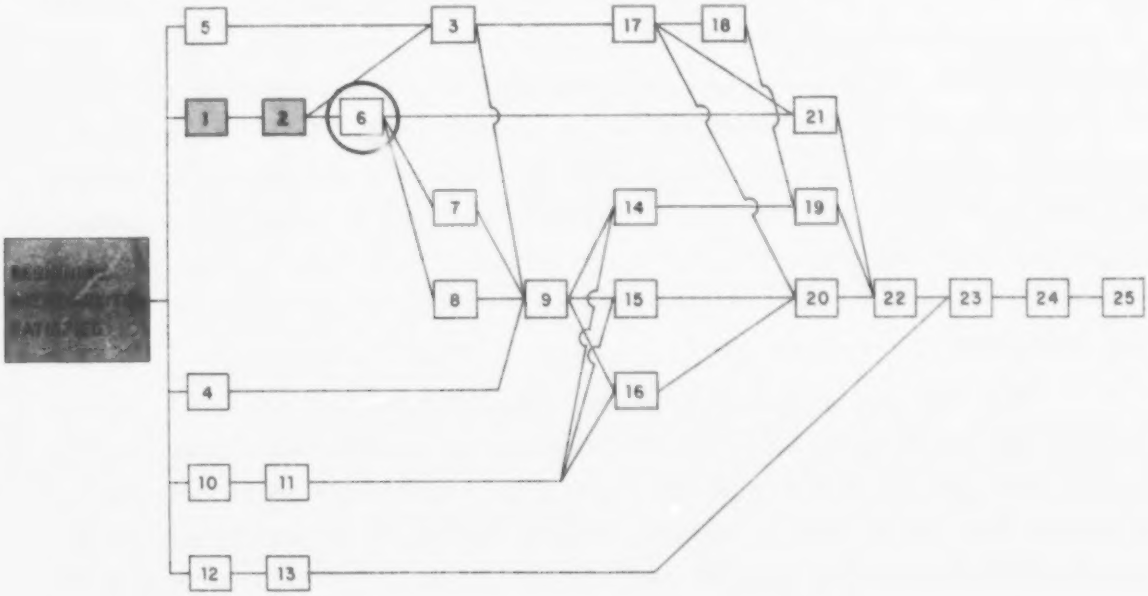

Fig. 29. Prerequisites for Step 6

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*If you are using AQDM, see Appendix G, Sec. 7.

Table 8. Resource Requirements for Step 6

Necessary Skills[a]	Necessary Data	Data Sources	Necessary Hardware
Data Analysis Cartographic Secretarial Possibly: Air Pollution Control Expertise	Simplified Zoning Maps and General Regional Map	Steps 1 and 2	None

[a] First on list directs this step.

- Location of the source in UTM or other coordinates.*
- Emission rates for SO_2 and particulates.
- Stack height and diameter.
- Exit velocity of stack gases (or stack gas flow rate).
- Temperature of stack gases.

Setting emission density limits clearly would be a mammoth undertaking if you had to collect these data "from scratch." However, the Clean Air Act requires states to compile comprehensive emission inventories that include this information. The state information has been transferred to the U.S. EPA's National Emissions Data System (NEDS), which is updated periodically. With the data collection already complete, all you need to do is to acquire the data from your region's state government(s) or the U.S. EPA. It is recommended that state or local data be used if they are available as they will probably be updated more quickly than NEDS. State data should be available on computer tape from the state EPA or its equivalent. NEDS data on tape may be ordered from the U.S. EPA regional offices (see Fig. 30 for phone numbers and addresses.)

NEDS data are available on cards, computer tape, or printout. It takes roughly two weeks for an EPA regional office to process a request for data. The request must be made in writing and explain the exact data requested; there is a nominal charge. Your letter to the EPA regional office should list the counties in your region, and request, for each point source in each county, the data listed above.

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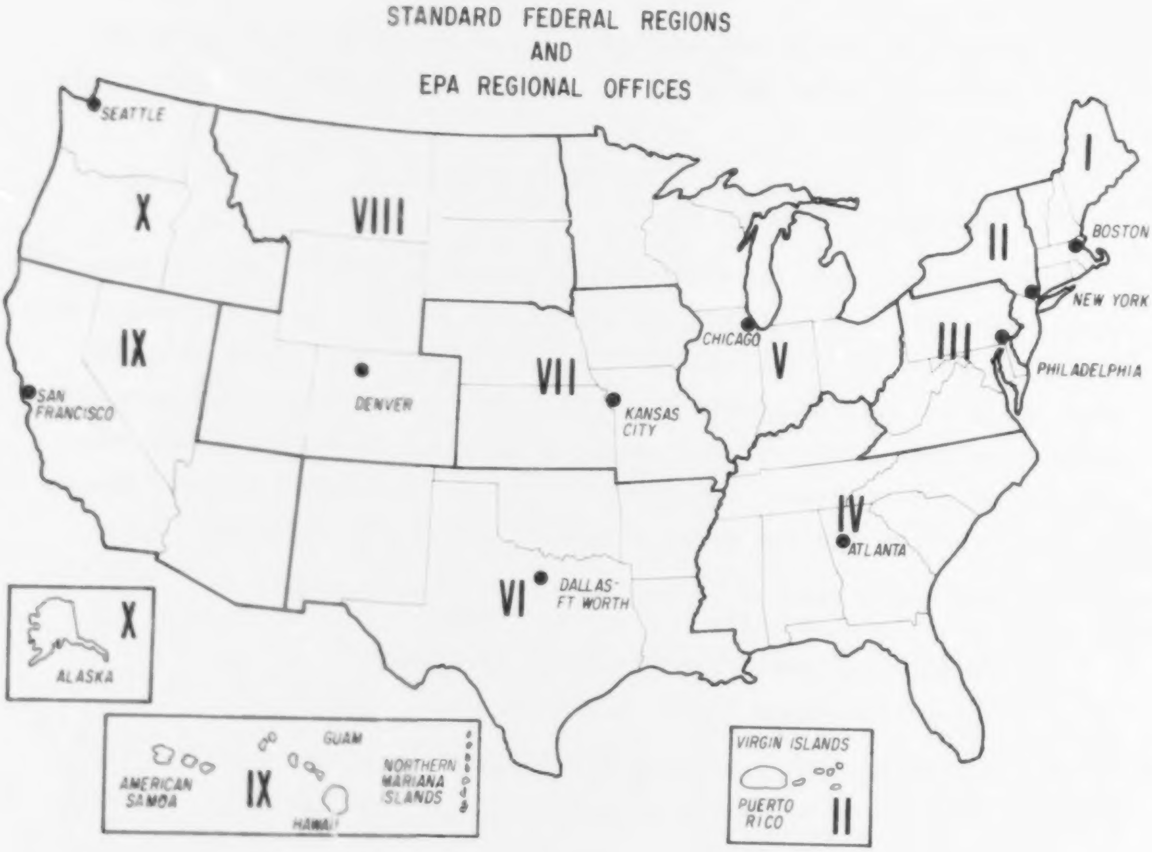
*See Appendices E and F.


STANDARD FEDERAL REGIONS
AND
EPA REGIONAL OFFICES
SEATTLE
X
VIII
I
II
BOSTON
NEW YORK
IX
III
CHICAGO
V
PHILADELPHIA
SAN FRANCISCO
DENVER
VII
KANSAS CITY
IV
ATLANTA
VI
DALLAS-FT WORTH
X
ALASKA
GUAM
AMERICAN SAMOA
IX
NORTHERN MARIANA ISLANDS
HAWAII
VIRGIN ISLANDS
PUERTO RICO
II

Region	Regional Office Telephone	NEDS Contact Telephone	Regional Office, NEDS Contact Address
I	(617) 223-7223	(617) 223-4448	John F. Kennedy Federal Bldg., Boston, MA 02203
II	(212) 264-2515	(212) 264-9578	26 Federal Plaza, New York, NY 10007
III	(215) 597-9370	(215) 597-8133	6th & Walnut Sts., Philadelphia, PA 19106
IV	(404) 881-3004	(404) 881-2864	345 Courtland N.E., Atlanta, GA 30308
V	(312) 353-2000	(312) 353-2303	230 S. Dearborn St., Chicago, IL 60604
VI	(214) 767-2600	(214) 749-3837	1201 Elm St., Dallas, TX 75270
VII	(816) 374-5894	(816) 374-3791	1735 Baltimore Ave., Kansas City, MO 64108
VIII	(303) 837-4905	(303) 837-4261	1860 Lincoln St., Denver, CO 80203
IX	(415) 556-6695	(415) 556-2326	215 Freemont St., San Francisco, CA 94105
X	(206) 442-1203	(206) 442-1580	1200 6th Ave., Seattle, WA 98101

Fig. 30. U.S. EPA Regional Offices

If the data needed are not available on the emission inventories, contact state or federal air pollution control agencies or the point source operators.

STEP 6B: ACQUIRE AREA SOURCE DATA

Area source data are also included in the NEDS file, but are arranged on a county basis. County data can be used in EDZ, but it is preferable to have area-source emissions computed over a smaller area. State EPAs and local pollution control boards have been required to perform extensive air quality analyses. Part of their work has involved allocating county emissions to subcounty areas. The results of these air quality analyses should be available from state or local units. The specific data required are:

- UTM coordinates of the emission grid squares used to allocate emissions to subcounty areas.*
- Emission estimates for SO_2 and particulates.
- Estimated average stack heights.**

The year for which these calculations were made should be the same as the year for which the point source and monitoring station data were recorded.

STEP 6C: MAKE ENGLISH-TO-METRIC CONVERSIONS FOR EMISSION INVENTORY

Unit conversions (English-to-metric) are likely to be required to prepare the emission inventory data collected in Steps 6A and 6B for coding and keypunching (Step 9). In addition, the coordinate system used in the emission inventory must be made consistent with the EDZ grid system.

By this time, you should be familiar with the emission inventory data. If the data are expressed in English units, they must be converted to metric equivalents (see Table 9).** The conversion factors are given in Appendix C. The conversions shown in Table 9 must be made for each point and area source in the inventory. Use Worksheets 6 and 7 (shown in Figs. 31 and 32) to

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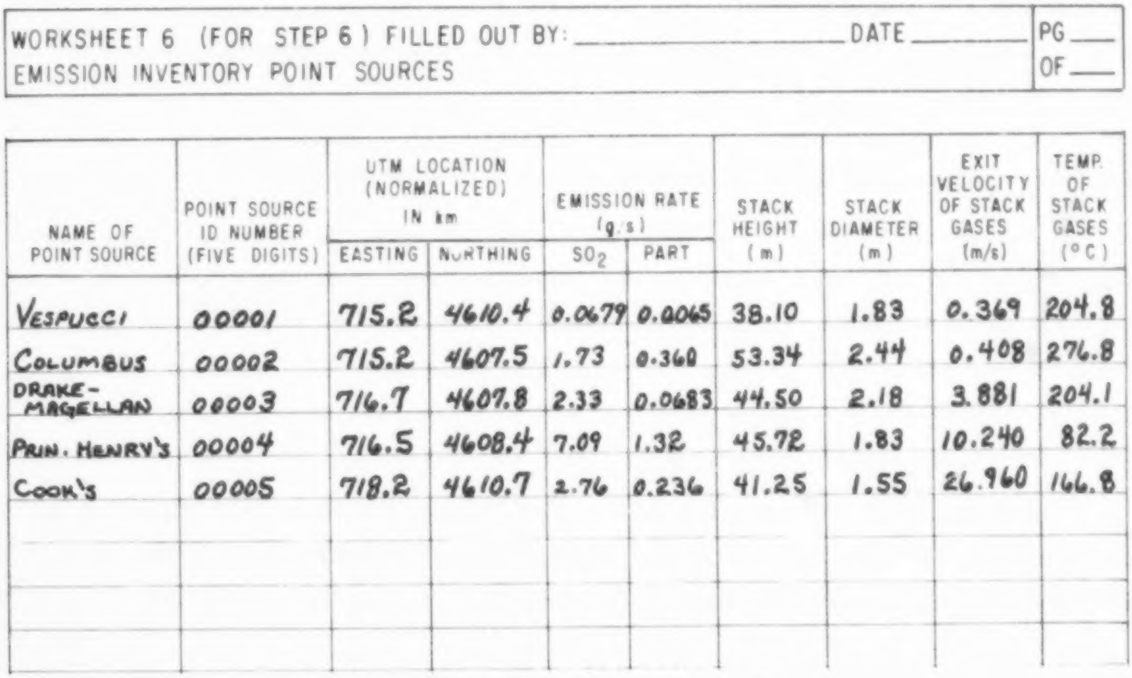
*These grid squares need not correspond to the EDZ grid system set up in Step 2. If the emission inventory uses a grid system other than UTM, see Appendix F.

**If you are using AQDM, see Appendix G, Sec. 8.

Table 9. Metric Units Needed for Emission Inventory Data

Variable	Units Most Likely Used in Emission Inventory	Units Required for CDMQC[a]
Point Sources		
UTM Location	kilometers	kilometers
Emission Rates	tons/year	grams/second
Stack Height	feet	meters
Stack Diameter	feet	meters
Exit Velocity of Stack Gas	flow rate (ft^3/min)	meters/second
Stack Gas Temperature	degrees Fahrenheit	degrees Celsius
Area Sources		
UTM Location of Southwest Corner of the Area Source Grid Square	kilometers or miles	kilometers
Width of the Area Source Grid Square	kilometers or miles	meters
Area Source Emission Rate (SO_2 and Particulates)	tons/year	grams/second
Estimated Average Stack Height	feet	meters

[a] See Appendix G, Sec. 8, if you are using AQDM.



WORKSHEET 6 (FOR STEP 6) FILLED OUT BY: ________________ DATE ________ PG ___
EMISSION INVENTORY POINT SOURCES OF ___

NAME OF POINT SOURCE	POINT SOURCE ID NUMBER (FIVE DIGITS)	UTM LOCATION (NORMALIZED) IN km		EMISSION RATE (g/s)		STACK HEIGHT (m)	STACK DIAMETER (m)	EXIT VELOCITY OF STACK GASES (m/s)	TEMP. OF STACK GASES (°C)
		EASTING	NORTHING	SO_2	PART				
VESPUCCI	00001	715.2	4610.4	0.0679	0.0065	38.10	1.83	0.369	204.8
COLUMBUS	00002	715.2	4607.5	1.73	0.360	53.34	2.44	0.408	276.8
DRAKE-MAGELLAN	00003	716.7	4607.8	2.33	0.0683	44.50	2.18	3.881	204.1
PRIN. HENRY'S	00004	716.5	4608.4	7.09	1.32	45.72	1.83	10.240	82.2
COOK'S	00005	718.2	4610.7	2.76	0.236	41.25	1.55	26.960	166.8

Fig. 31. Worksheet 6 Example

WORKSHEET 7 (FOR STEP 6) FILLED OUT BY:__________ DATE:__________ PG____ OF____

EMISSION INVENTORY AREA SOURCES

AREA SOURCE I.D. NUMBER FROM EMISSION INVENTORY (5 DIGITS)	UTM LOCATION (NORMALIZED) OF S.W. CORNER OF THE GRID SQUARE (km)		WIDTH OF THE GRID SQUARE (m)	EMISSION RATE (g/s)		ESTIMATED AVERAGE STACK HEIGHT (m)
	EASTING	NORTHING		SO_2	PART	
00143	710.55	4604.22	4000	18.06	22.24	7.5
00144	710.55	4608.22	4000	18.06	22.24	7.5
00165	714.55	4604.22	4000	35.07	58.20	10.0
00166	714.55	4608.22	4000	68.18	65.00	10.0
00187	718.55	4604.22	4000	30.01	35.06	10.0
00188	718.55	4608.22	4000	63.02	72.43	10.0
00301	722.55	4604.22	2000	9.13	18.27	5.0

Fig. 32. Worksheet 7 Example

facilitate the computations.* See Appendix E if you have to deal with a UTM grid junction,** and consult Appendix F if the emission inventory data are not provided in UTM coordinates.

STEP 6D: PREPARE EMISSION INVENTORY DATA FOR USE IN STEP 21

The purpose of this substep is to process emission inventory data for use in Step 21. First, secure the point source data from the emission inventory, and, by using the gridded simplified zoning maps and the general regional map produced in Steps 1 and 2, find the simplified land use zoning classification of each source. Record this information on Worksheet 8 (Fig. 33), listing all light, medium, and heavy manufacturing land uses separately.

Second, find the emission rate (g/s) for each source from the emission inventory or Worksheet 6, and enter these data on Worksheet 8. Third, if this information is in the emission inventory, list the land area (in

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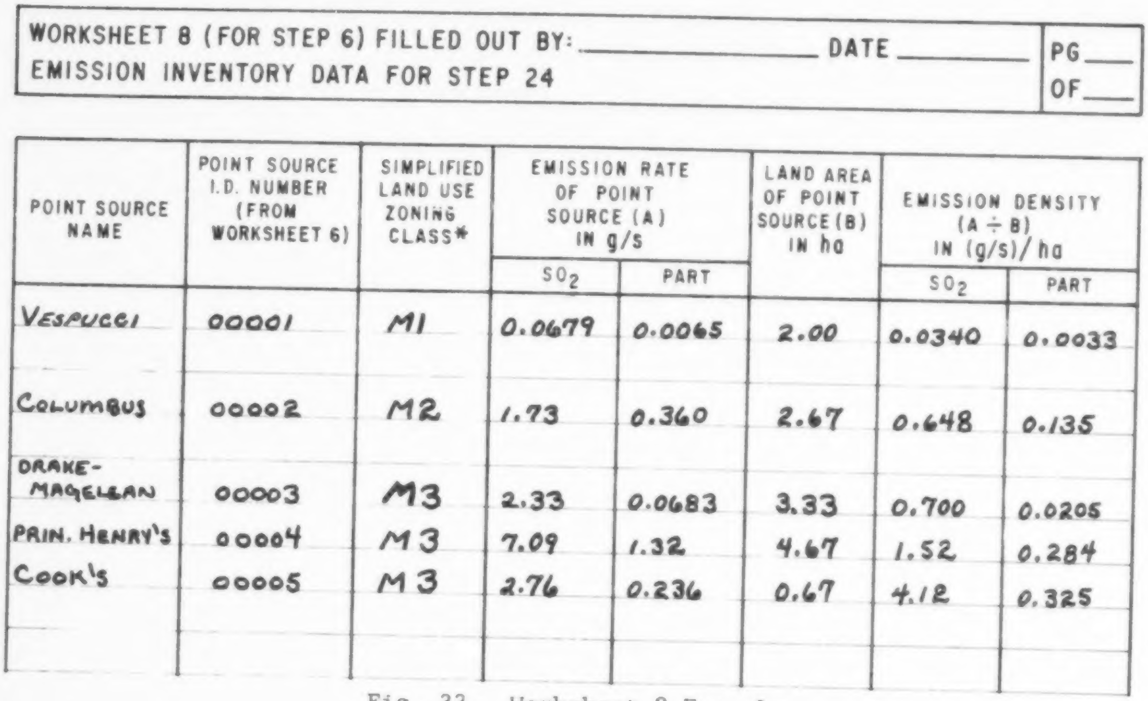
*Full page, blank worksheets for your use are provided in Appendix J.

**An explanation of these is provided in Step 1.



WORKSHEET 8 (FOR STEP 6) FILLED OUT BY: ________ DATE ________ PG ___ OF ___

EMISSION INVENTORY DATA FOR STEP 24

POINT SOURCE NAME	POINT SOURCE I.D. NUMBER (FROM WORKSHEET 6)	SIMPLIFIED LAND USE ZONING CLASS*	EMISSION RATE OF POINT SOURCE (A) IN g/s		LAND AREA OF POINT SOURCE (B) IN ha	EMISSION DENSITY (A ÷ B) IN (g/s)/ha	
			SO_2	PART		SO_2	PART
Vespucci	00001	M1	0.0679	0.0065	2.00	0.0340	0.0033
Columbus	00002	M2	1.73	0.360	2.67	0.648	0.135
Drake-Magellan	00003	M3	2.33	0.0683	3.33	0.700	0.0205
Prin. Henry's	00004	M3	7.09	1.32	4.67	1.52	0.284
Cook's	00005	M3	2.76	0.236	0.67	4.12	0.325

Fig. 33. Worksheet 8 Example

hectares) covered by the source's property in the appropriate column. If the areas are not in the inventory, find them by using existing maps, tax records, or calling the operator of the emission source.

Finally, divide each source's emission rate by its land area and record the results in the right-hand column. These data are to be held for use in Step 21.*

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*If you are using AQDM, see Appendix G, Sec. 8.

STEP 7: ESTIMATE EMISSIONS OF EXEMPT SOURCES

SUMMARY

In this step you will estimate the emissions of sources that you have decided to classify as "exempt sources," "sources granted automatic compliance," or "nonconforming uses." The decision on which sources to so classify should have been made before the 25-step EDZ methodology was begun -- see the discussion of Prerequisite 6 on pages 10-12 of the guidebook Introduction.

The contributions to air pollutant concentrations at each receptor of these sources must be estimated to ensure that air quality standards will not be violated. The emission estimates made in Step 7 are used in Step 16 to determine these contributions. If you have decided to exempt some sources from EDZ, Step 7 must be completed.

If your region has no exempt sources, you may decide to treat existing sources as nonconforming uses as discussed in the Introduction. In this case ignore the guidebook references to exempt and automatic compliance sources and complete the methodology with whatever gaps may exist in Worksheets 10, 13, and 14. The gaps will affect the EDLs determined for the region, but will not affect your ability to complete the methodology.

The substeps involved in Step 7 are:

Step 7A: Estimate Emissions of Exempt Area Sources
Step 7B: Estimate Emissions of Exempt Power Plants, Incinerators, and Other Special Sources
Step 7C: Estimate Emissions of Existing Point Sources Granted Automatic Compliance Status

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

The prerequisites outlined in the Introduction must be fulfilled and Steps 1, 2, and 6 completed, as illustrated by Fig. 34. The personnel and data requirements for Step 7 are listed in Table 10.

STEP 7A: ESTIMATE EMISSIONS OF EXEMPT AREA SOURCES

An area source may generally be defined as an aggregation of many small sources. For example, mobile, residential, commercial, small

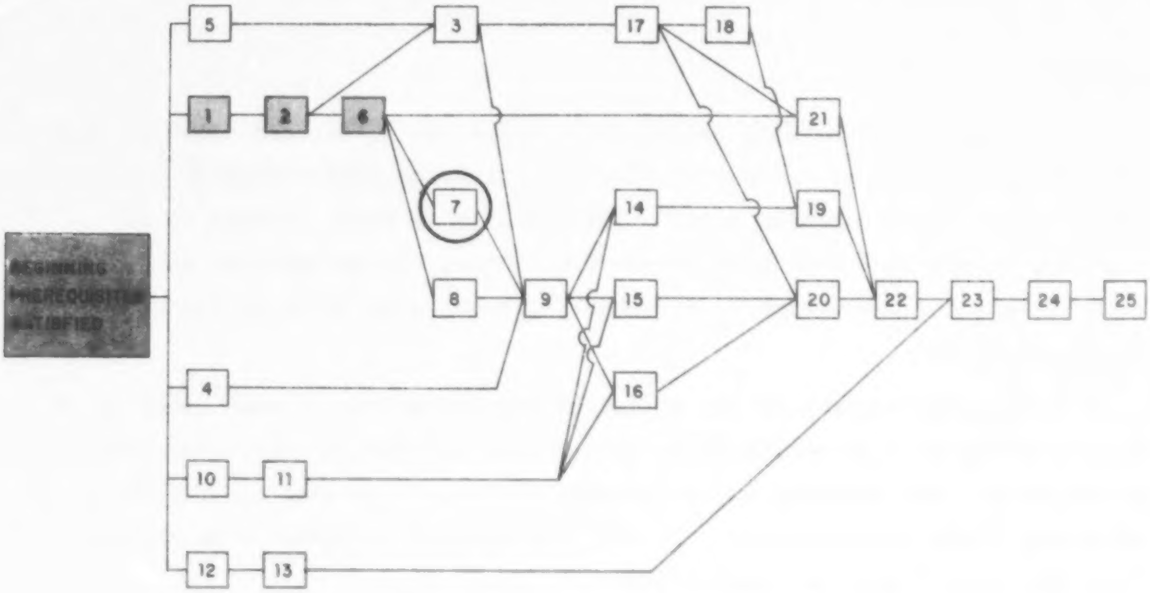

Fig. 34. Prerequisites for Step 7

industrial, and agricultural sources and rights of way may be aggregated into an equivalent area source. Each individual structure emits very little sulfur dioxide and particulate matter, too little to justify a detailed review or to make EDZ control practical. In aggregate, however, emissions from area sources can be significant, and therefore their air quality contributions should be included in setting EDLs.

The air pollution contributions due to area source emissions in some future year* must be estimated and included in the linear program. The estimates should be made to account for possible changes in emissions due to growth, changes in environmental control policy, and/or changes in energy consumption patterns. To make these projections, follow the directions provided in the EPA reports:

> *Guidelines for Air Quality Maintenance Planning and Analysis. Volume 7: Projecting County Emissions* (EPA-450/4-74-008) and *Volume 13: Allocating Projected Emissions to Subcounty Areas* (EPA-450/4-74-014)

These documents may be obtained from: Library Services Branch, Mail Drop 35, Environmental Protection Agency, Research Triangle Park, NC 27711.

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*For example, 10 or 20 years into the future may be considered a suitable time horizon.

Table 10. Resource Requirements for Step 7

Necessary Skills[a]	Necessary Data	Data Sources	Necessary Hardware
Air Pollution Control Expertise Land Use Planning Data Analysis	Exemptions Decision	Prerequisites	None
	Zoning Maps and Ordinances	Step 2	
	Gridded Regional Map	Step 2	
	Emission Inventory	Step 6	
	EPA Guidebooks	See text	

[a] First on list directs this step.

The projections generated by these procedures, which are handled in exactly the same way as the area source emission inventory data were handled in Step 6, are to be entered on Worksheet 9 (Fig. 35).* It may be helpful to photocopy Worksheet 7 since its first four columns are identical to those on Worksheet 9. Worksheet 9 requires that the average stack characteristics for future area sources be estimated. The estimation procedure is explained in Step 8.

STEP 7B: ESTIMATE EMISSIONS FOR EXEMPT POWER PLANTS, INCINERATORS, AND OTHER SPECIAL SOURCES

If the decision has been made to exempt power plants, incinerators, and other special point sources, the following steps should be completed to estimate the emissions from these sources:

1. Find out the current and approximate future locations and land areas of these sources (probably from utility company or municipal records and plans).
2. Locate the EDZ grid squares that contain the existing and proposed facilities.
3. Determine the land use zoning classification(s) of the facilities.
4. For each grid square, subtract the quantity of land used by each facility from the total amount of land in the same zoning classification. *The remaining value will be considered the amount of land zoned in the zoning class in the grid square for the linear programming calculations in Steps 18 - 22; therefore, the land areas written into Worksheet 2 must be changed.*

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*Full page, blank worksheets for your use are provided in Appendix J.

WORKSHEET 9 (FOR STEP 7) FILLED OUT BY:__________ DATE:__________ PG____
AREA SOURCE EXEMPTIONS OF____

AREA SOURCE ID NUMBER* (5 DIGITS)	UTM LOCATION (NORMALIZED) OF S.W. CORNER OF THE GRID SQUARE (km)		WIDTH OF THE GRID SQUARE (m)	FUTURE EMISSION RATE (g/s)		AVERAGE STACK HEIGHT (m)
	EASTING	NORTHING		SO_2	PART	
00143	710.55	4604.22	4000	22.00	25.00	7.5
00144	710.55	4608.22	4000	20.00	23.50	7.5
00165	714.55	4604.22	4000	38.50	60.00	10.0
00166	714.55	4608.22	4000	55.00	60.00	10.0
00187	718.55	4604.22	4000	40.00	53.00	10.0
00188	718.55	4608.22	4000	60.00	72.50	10.0
00301	722.55	4604.22	2000	12.00	23.00	5.0
00303	722.55	4606.22	2000	5.00	10.00	5.0
00305	722.55	4608.22	2000	5.00	9.50	5.0
00307	722.55	4610.22	2000	10.00	20.00	5.0

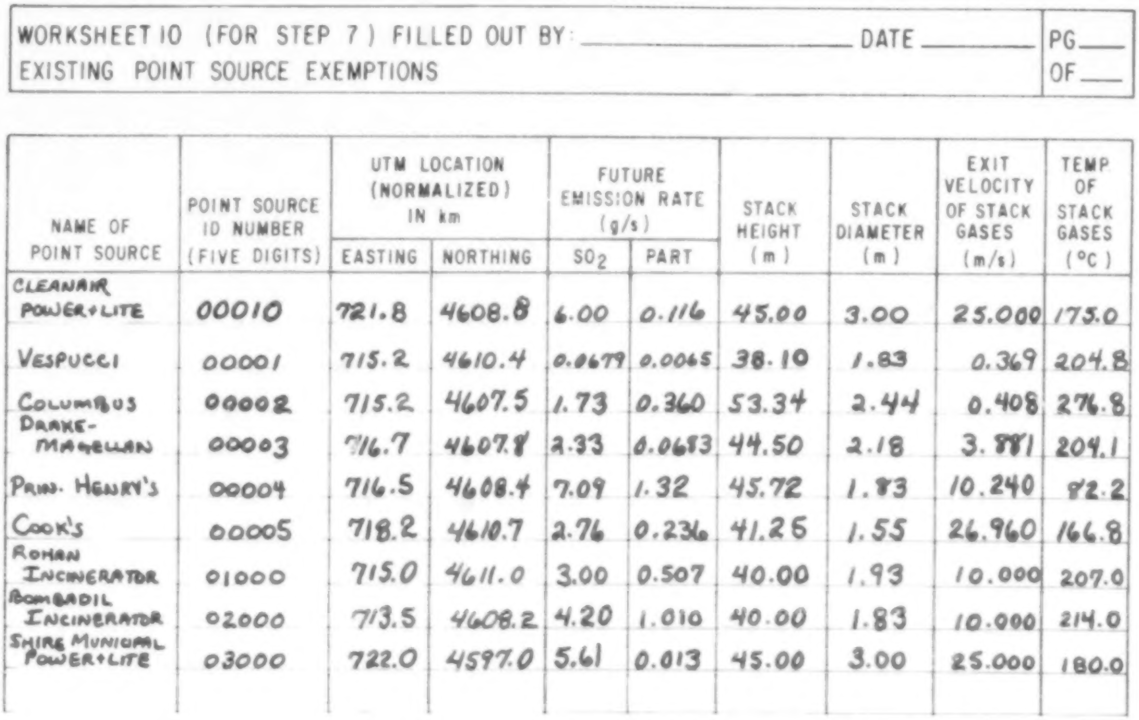
Fig. 35. Worksheet 9 Example

5. Estimate the emission and stack characteristics expected for the facilities (probably from utility company or governmental records and plans. Enter these estimates on Worksheet 10, shown in Fig. 36 (a photocopy of Worksheet 6's first four columns may be useful).

STEP 7C: ESTIMATE EMISSIONS FROM EXISTING POINT SOURCES GRANTED AUTOMATIC COMPLIANCE STATUS

The concept and procedures behind existing sources given automatic compliance status is the same as for area sources and point sources being given exemptions from EDZ. The only difference is that a choice must be made on whether the EDLs set for these sources are set at their current or projected emission densities. This choice is a political or legal decision which depends on whether or not the automatic compliance is going to allow future increases in emission densities of existing sources.

If current emissions and site areas are used these would be obtained directly from the emission inventory data collected in Step 6. If projected



WORKSHEET 10 (FOR STEP 7) FILLED OUT BY: ______	DATE ______	PG ___
EXISTING POINT SOURCE EXEMPTIONS		OF ___

NAME OF POINT SOURCE	POINT SOURCE ID NUMBER (FIVE DIGITS)	UTM LOCATION (NORMALIZED) IN km		FUTURE EMISSION RATE (g/s)		STACK HEIGHT (m)	STACK DIAMETER (m)	EXIT VELOCITY OF STACK GASES (m/s)	TEMP OF STACK GASES (°C)
		EASTING	NORTHING	SO_2	PART				
CLEANAIR POWER+LITE	00010	721.8	4608.8	6.00	0.116	45.00	3.00	25.000	175.0
VESPUCCI	00001	715.2	4610.4	0.0679	0.0065	38.10	1.83	0.369	204.8
COLUMBUS	00002	715.2	4607.5	1.73	0.360	53.34	2.44	0.408	276.8
DRAKE-MAGELLAN	00003	716.7	4607.8	2.33	0.0683	44.50	2.18	3.881	204.1
PRIN. HENRY'S	00004	716.5	4608.4	7.09	1.32	45.72	1.83	10.240	82.2
COOK'S	00005	718.2	4610.7	2.76	0.236	41.25	1.55	26.960	166.8
ROHAN INCINERATOR	01000	715.0	4611.0	3.00	0.507	40.00	1.93	10.000	207.0
BOMBADIL INCINERATOR	02000	713.5	4608.2	4.20	1.010	40.00	1.83	10.000	214.0
SHIRE MUNICIPAL POWER+LITE	03000	722.0	4597.0	5.61	0.013	45.00	3.00	25.000	180.0

Fig. 36. Worksheet 10 Example

emissions are used, the emission rates are estimated using the two EPA manuals listed in Step 7A. The following steps need to be completed:

1. Determine the locations and land areas of sources to be granted automatic compliance status (from the emission inventory data collected in Step 6).
2. Locate the EDZ grid squares that contain the sources.
3. Determine the land use zoning classification of the sources.
4. For each grid square, subtract the quantity of land zoned for each new source from the total amount of land in the same zoning classification. *The remaining value will be considered the amount of land zoned in the zoning class in the grid square for the linear programming calculations in Steps 18 - 22. Therefore, the land areas on Worksheet 2 must be changed.*
5. Determine emission and stack characteristics of the sources (from the emission inventory of Step 6). If projected emissions are to be used in setting EDLs, consult the EPA manuals listed in Step 7A. Enter the emissions and stack characteristics on Worksheet 10.

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STEP 8: DETERMINE STACK CHARACTERISTICS

SUMMARY

In Step 8, you will obtain, calculate, or predict individual source and average stack characteristics for use in the dispersion model runs. For CDMQC, the stack characteristics needed are stack height and diameter, exit gas velocity, and exit gas temperature.*

Three substeps are involved:

Step 8A: Determine Stack Heights for the Air Quality Runs of the Dispersion Model

Step 8B: Determine Stack Characteristics for the Calibration Run of the Dispersion Model

Step 8C: Determine Stack Characteristics for the Right-Hand-Side Run of the Dispersion Model

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

Before you begin Step 8, the prerequisites outlined in the Introduction must be fulfilled and Steps 1, 2, and 6 completed, as illustrated in Fig. 37. Personnel and data requirements are listed in Table 11.

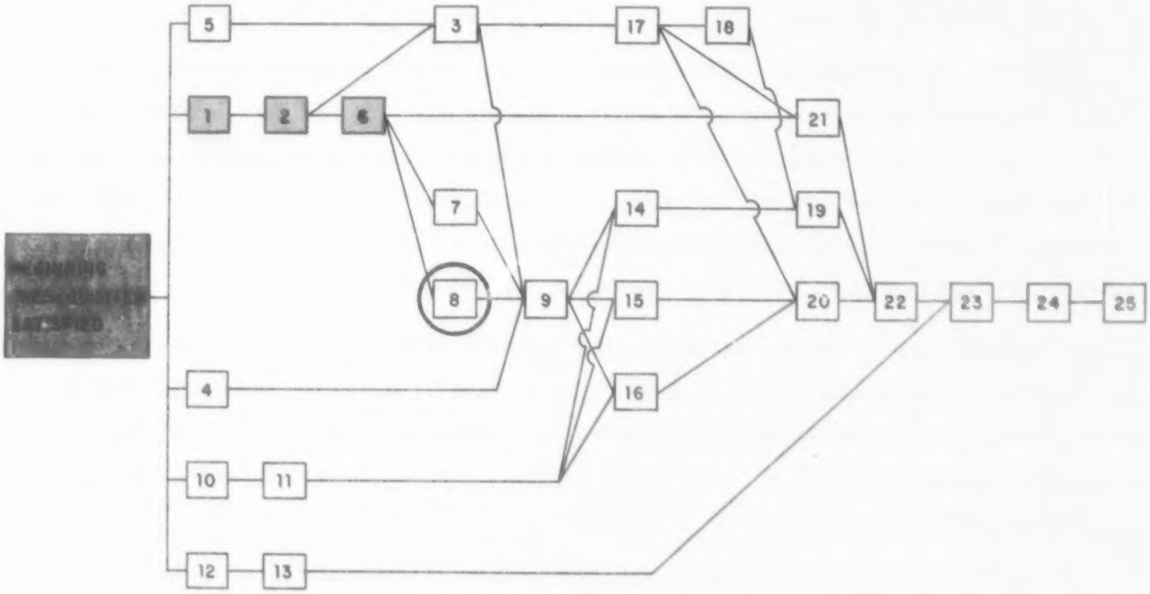

Fig. 37. Prerequisites for Step 8

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*If you are using AQDM, see Appendix G, Sec. 8.

Table 11. Resource Requirements for Step 8

Necessary Skills[a]	Necessary Data	Data Sources	Necessary Hardware
Air Pollution Control Expertise Land Use Planning Data Analysis	Exemptions Decision	Prerequisites	None
	Zoning Maps and Ordinances	Step 2	
	Emission Inventory	Step 6	

[a] First on list directs this step.

STEP 8A: DETERMINE STACK HEIGHTS FOR THE AIR QUALITY RUNS OF THE DISPERSION MODEL

The emission inventory provides the data required to estimate average stack heights for the light, medium, and heavy manufacturing sources.

Determine which point sources are located in which zoning classes (the zoning class of each source is listed on Worksheet 8), and list these on Worksheet 11, shown in Fig. 38.* Sources with the same zoning classification should be listed together on Worksheet 11. Also list the stack heights on Worksheet 11. This information should be included in the emission inventory data collected in Step 6.

Then, after you have identified all the point sources, average the stack heights within each zoning class. Simple arithmetic means are to be used; that is, all stack heights within a zoning class are summed and divided by the number of sources in the class. You should have four numbers when you complete Step 8A: the average stack heights for light, medium, and heavy manufacturing sources; and an average for all sources combined.

Contact your local air pollution control authority to determine whether these average stack heights conform to current building practices and U.S. EPA policies on stack height allowances for dispersion modeling. If the averages appear acceptable, use them; if not, the averages should be changed to conform with EPA policy.

These actual stack height estimates may be assumed to be equal to the effective stack height for the light, medium, and heavy manufacturing area sources. This is a conservative assumption -- it will result in lower

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*Full-page blank worksheets for your use are provided in Appendix J.

WORKSHEET 11 (FOR STEP 8) FILLED OUT BY: ____________ DATE ________ PG ___ OF ___
STACK HEIGHTS FOR AIR QUALITY RUNS

POINT SOURCE NAME	POINT SOURCE NUMBER (FROM WORKSHEET 6)	SIMPLIFIED LAND USE ZONING CLASS	STACK HEIGHT FROM WORKSHEET 6 (m)
VESPUCCI	0003	M1	38.10
COLUMBUS	0002	M2	53.34
DRAKE-MAGELLAN	0001	M3	44.50
PRINCE HENRY'S	0004	M3	45.72
COOK'S	0005	M3	41.15
		AVERAGE FOR M-1 =	$\frac{38.10}{1}$ = 38.10 m
		AVERAGE FOR M-2 =	$\frac{53.34}{1}$ = 53.34 m
		AVERAGE FOR M-3 =	$\frac{131.37}{3}$ = 43.79 m
		AVERAGE FOR ALL POINT SOURCES =	$\frac{222.81}{5}$ = 44.56m

Fig. 38. Worksheet 11 Example

emission density limits than if an actual effective height was used. If a less conservative average effective stack height estimate is desired, then for each point source in the emission inventory an average effective stack height should be calculated. Check with your local air pollution control agencies or the U.S. EPA to determine an acceptable procedure in your area for making these estimates.

Then, substituting these effective stack heights for the actual stack heights in Worksheet 11 and following the procedures described in Step 8A will result in alternative estimates of stack heights.

STEP 8B: DETERMINE STACK CHARACTERISTICS FOR THE CALIBRATION RUN OF THE DISPERSION MODEL

The stack characteristics needed for the calibration run are included in the emission inventory data in Step 6. If all the entries in Worksheet 6 have been completed, no further work need be done except that a regional average (arithmetic mean) stack height must be calculated by summing the stack heights for all the point sources in the region and dividing by the total number of point sources. This regional average stack height should be used as the value for H needed to calculate the SZA value on the Type 5 Card for the CDMQC calibration run (see Fig. 54 in Step 9).

STEP 8C: DETERMINE STACK CHARACTERISTICS FOR THE RIGHT-HAND-SIDE RUN OF THE DISPERSION MODEL

The right-hand-side (RHS) run usually involves future emissions of EDZ exempt sources. In addition to emissions, estimates of the future stack characteristics of some exempt sources are required. All data described below are to be placed in the appropriate columns of Worksheets 9 and 10.

Exempt Area Sources. CDMQC only requires average effective stack heights for area sources. For EDZ, it is assumed that future area source stack heights will not be significantly different than they are currently. Area source stack data were collected with the emission inventory data in Step 6. Assume these are equal to effective stack heights.

Exempt Point Sources (and Point Sources Granted Automatic Compliance Status). Except for power plants, it should be assumed that future stack characteristics will be the same as they are currently unless (1) there is reason to believe that they will change or (2) current practice does not conform to the EPA's definition of "good engineering practice." Future power plant stack characteristics should be estimated based on utility company records. Stack heights for power plants should be estimated on the assumption that no future stack will be taller than the EPA stack height allowance for setting emission limits, i.e., the EPA's definition of good engineering practice.*

The average regional stack height calculated in Step 8B should be used as the H value need for the right-hand-side run Type 5 Card (see Fig. 55).

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*If there are stack characteristic restrictions in the land use zoning ordinance, or local building codes, then these may affect future stack characteristics. For example, if there are height restrictions in certain areas of the region (such as near airports), the limitations must be taken into consideration when heights are estimated.

STEP 9: CODE AND KEYPUNCH DISPERSION MODEL INPUT DATA

SUMMARY

In Step 9 the data processed in Steps 2 - 8 are coded and keypunched for input to the dispersion model.* Since CDMQC is the model recommended for EDZ, Step 9 applies only to the input sequence for CDMQC. If you are using AQDM or another dispersion model, Step 9 does not apply; consult the user's manual for your dispersion model regarding input data format.

The person in charge of Step 9 should reread the section entitled "Dispersion Modeling and Its Use in EDZ" before beginning this task. Step 9 explains the exact card formats required for the CDMQC runs: the light manufacturing, medium manufacturing, and heavy manufacturing air quality runs (performed in Step 14); calibration run (Step 15); and right-hand-side run (Step 16). Many of the cards input to CDMQC require modifications from run to run. Therefore, there will be as many as five versions of the same card.**

The substeps involved in Step 9 are:

Step 9A: Code and Keypunch General Data Cards
Step 9B: Code and Keypunch Point Source Cards
Step 9C: Code and Keypunch Area Source Cards
Step 9D: Code and Keypunch Monitoring Station Cards
Step 9E: Code and Keypunch EDZ Receptor Point Cards
Step 9F: Mark and Duplicate Card Decks

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

The data from Steps 2 - 8 must be collected and processed before you begin Step 9, as shown in Fig. 39. The personnel, data, and hardware needed for Step 9 are considerable, as shown in Table 12. The necessary data for this step include the CDM and CDMQC manuals:†

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*Coding is defined here as the act of writing data onto a page (called a coding form) so that, when keypunched, the data are in the exact form required for input into a computer. Keypunching is defined as the act of typing computer cards with the aid of coded data.

**You may need more than five versions of some cards if any of the situations described in Appendix I apply to your region.

†If you have completed Step 10, you will have already ordered these manuals.

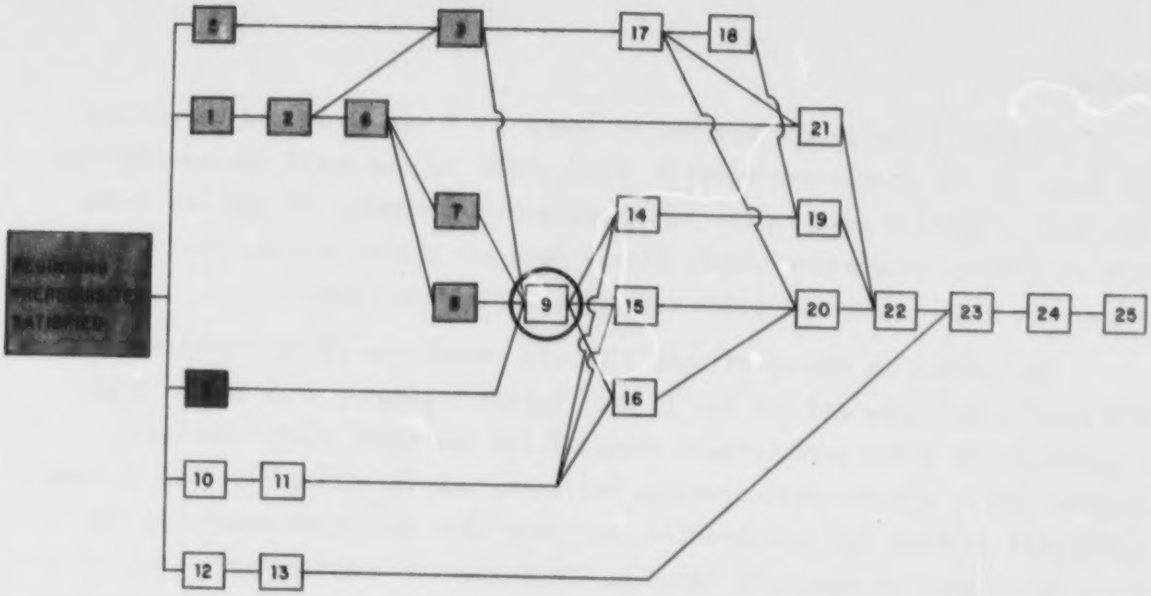

Fig. 39. Prerequisites for Step 9

Busse, A.D., and J.R. Zimmerman, *User's Guide for the Climatological Dispersion Model*, U.S. EPA Report EPA-R4-73-024, NTIS No. PB-227-346 (Dec. 1973).

Brubaker, K.L., P. Brown, and R.R. Cirillo, *Addendum to the User's Guide for the Climatological Dispersion Model*, U.S. EPA Report No. EPA-450/3-77-015 (July 1977).

These manuals are available from:

Modeling Support Section, Mail Drop 14
Source-Receptor Analysis Branch, Monitoring Data and Analysis Div.
Office of Air Quality Planning and Standards
Environmental Protection Agency
Research Triangle Park, NC 27711

RULES AND GENERAL INSTRUCTIONS FOR CODING AND KEYPUNCHING FOR CDMQC

This section is written for individuals with little or no experience with computer models and, in particular, with CDMQC. Although the guidebook is written for a wide range of potential users, it is strongly recommended that an experienced programmer be responsible for this step. Coding and keypunching data for CDMQC are very mechanical tasks. If the data processed in Steps 2 - 8 have been placed on the worksheets and Step 9 is followed carefully, there should be no problems in coding and keypunching.

Table 12. Resource Requirements for Step 9

Necessary Skills[a]	Necessary Data	Data Sources	Necessary Hardware
Computer Programming	EDZ Source Data	Step 2	Keypunch
Data Analysis	EDZ Receptors	Step 3	Organizing Files
Keypunching	Meteorological Data	Step 4	Coding Forms
	Monitoring Station Data	Step 5	
	Emission Inventory	Step 6	
	Exempt Sources	Step 7	
	Stack Characteristics	Step 8	
	CDM and CDMQC Manuals	U.S. EPA	

[a] First on list directs this step.

Rules

- Do everything exactly the way the guidebook says to do it.
- Be sure each number, letter, punctuation mark, and symbol is in the exact column indicated.
- No cards may be added to or removed from the deck.
- Be sure to check each coding form and punched card at least twice for accuracy. Punched cards should be verified mechanically.

General Instructions

- There are four kinds of data cards used in CDMQC. The first 101 cards, called general data cards, include meteorological data, the joint frequency function, and miscellaneous control parameters. The second kind, point source cards, give information on up to 200 point sources in the region.* Area source cards provide data for up to 2500 area sources. Receptor point cards are used to describe EDZ receptors and monitoring station data.* These four card groups together make up a "data deck." There is one data deck for each CDMQC run. Data decks showing the order that the cards must be placed in for input into the computer are diagrammed in Figs. 40-42. A summary of the differences between each CDMQC run is presented in Table 13.
- Figure 43 illustrates the format of the pages used in the guidebook to explain card format. Each of these figures (Figs. 44-66) explains a single line to be entered on a coding form; each line on a coding form is typed on a single card. The cards must be placed into the deck in the order given in the guidebook. Be sure to note the *card number* and

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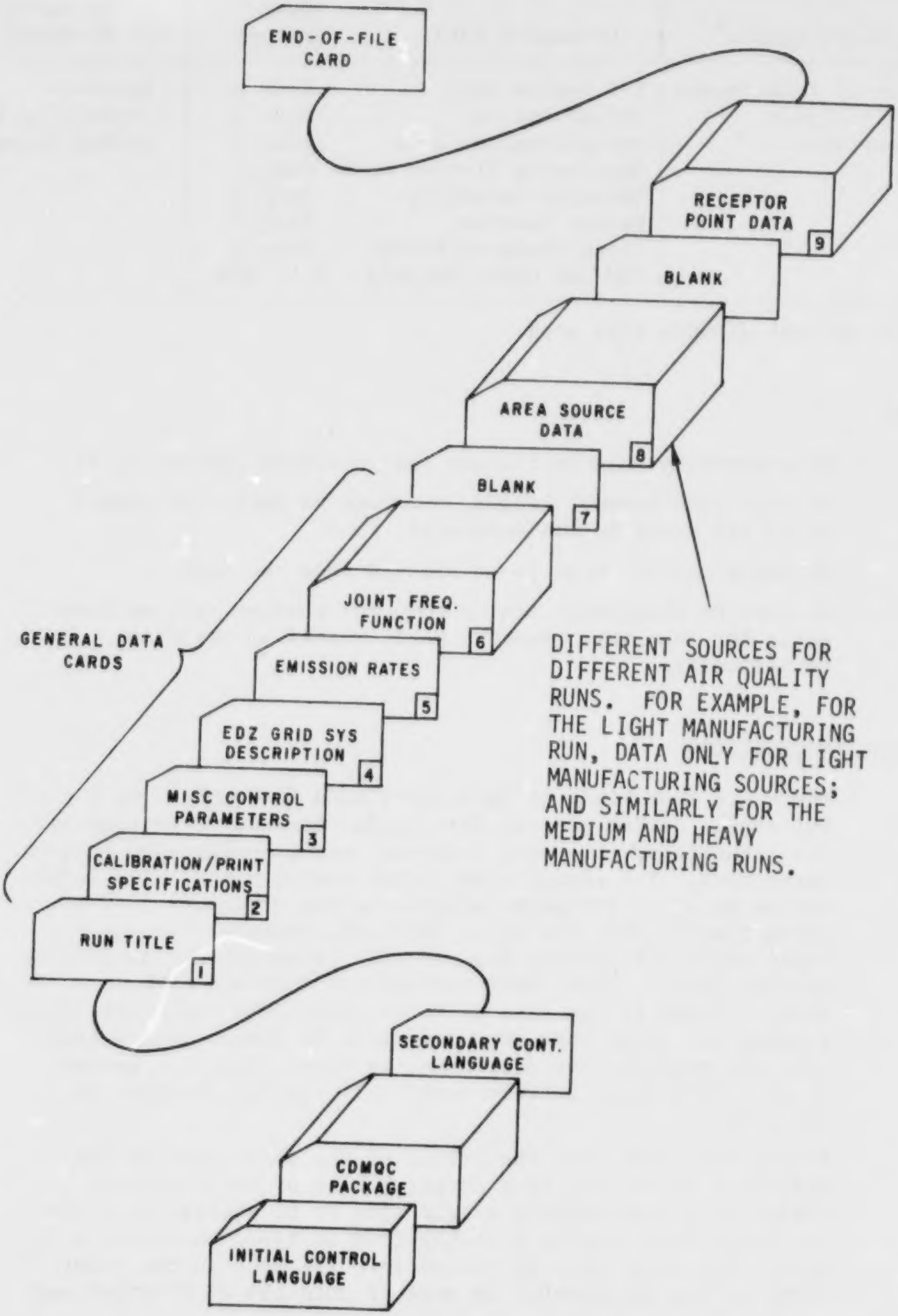
*If there are more than 200 point sources or receptor points in your region, or more than 50 monitoring stations, see Appendix I.


END-OF-FILE CARD
RECEPTOR POINT DATA
9
BLANK
AREA SOURCE DATA
8
BLANK
7
JOINT FREQ. FUNCTION
6
GENERAL DATA CARDS
EMISSION RATES
5
EDZ GRID SYS DESCRIPTION
4
MISC CONTROL PARAMETERS
3
CALIBRATION/PRINT SPECIFICATIONS
2
RUN TITLE
1
SECONDARY CONT. LANGUAGE
CDMQC PACKAGE
INITIAL CONTROL LANGUAGE

DIFFERENT SOURCES FOR DIFFERENT AIR QUALITY RUNS. FOR EXAMPLE, FOR THE LIGHT MANUFACTURING RUN, DATA ONLY FOR LIGHT MANUFACTURING SOURCES; AND SIMILARLY FOR THE MEDIUM AND HEAVY MANUFACTURING RUNS.

Fig. 40. CDMQC Card Input Sequence for Air Quality Runs

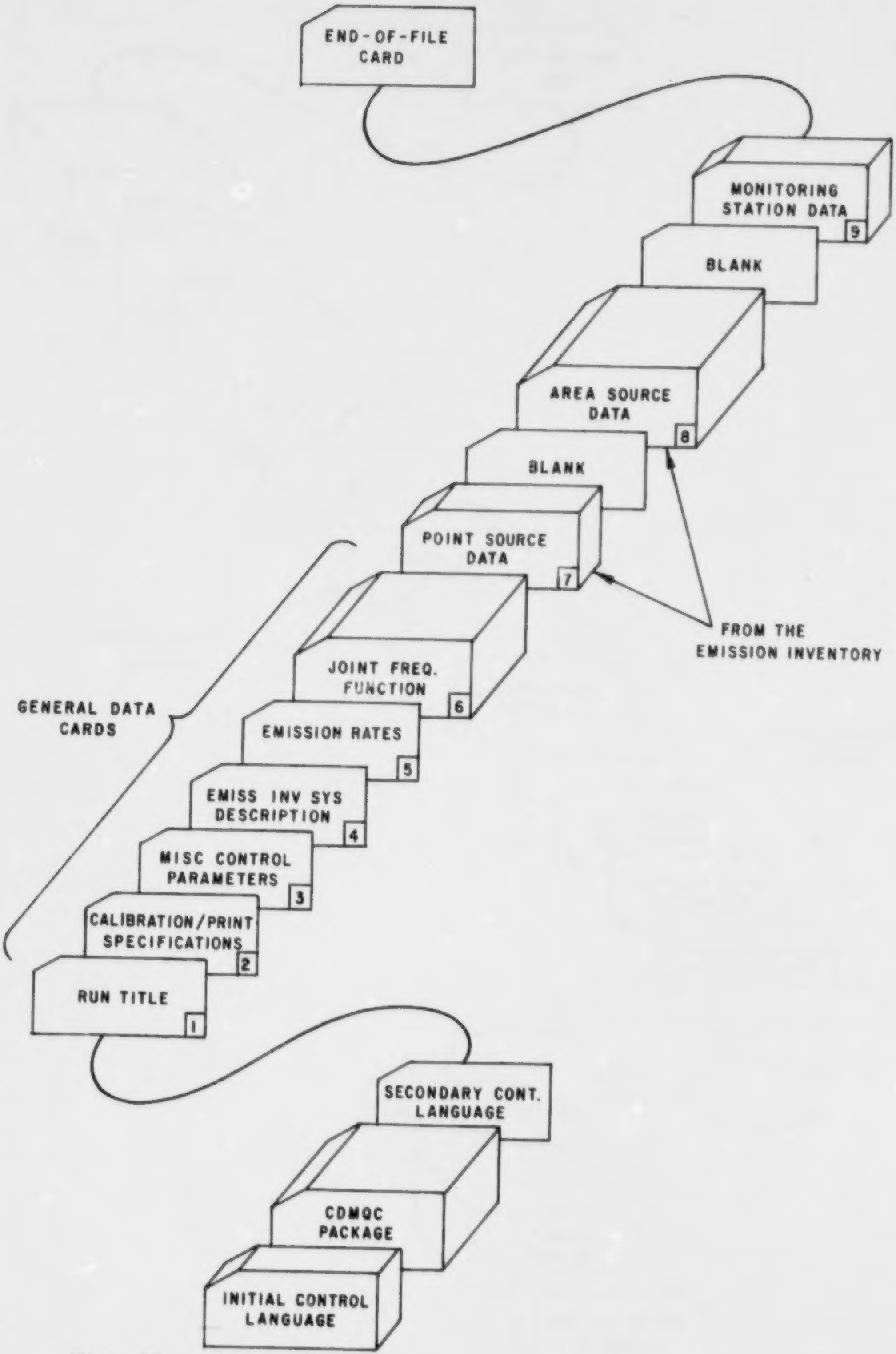

END-OF-FILE CARD
MONITORING STATION DATA
9
BLANK
AREA SOURCE DATA
8
BLANK
POINT SOURCE DATA
7
FROM THE EMISSION INVENTORY
JOINT FREQ. FUNCTION
6
GENERAL DATA CARDS
EMISSION RATES
5
EMISS INV SYS DESCRIPTION
4
MISC CONTROL PARAMETERS
3
CALIBRATION/PRINT SPECIFICATIONS
2
RUN TITLE
1
SECONDARY CONT. LANGUAGE
CDMQC PACKAGE
INITIAL CONTROL LANGUAGE

Fig. 41. CDMQC Card Input Sequence for Calibration Run

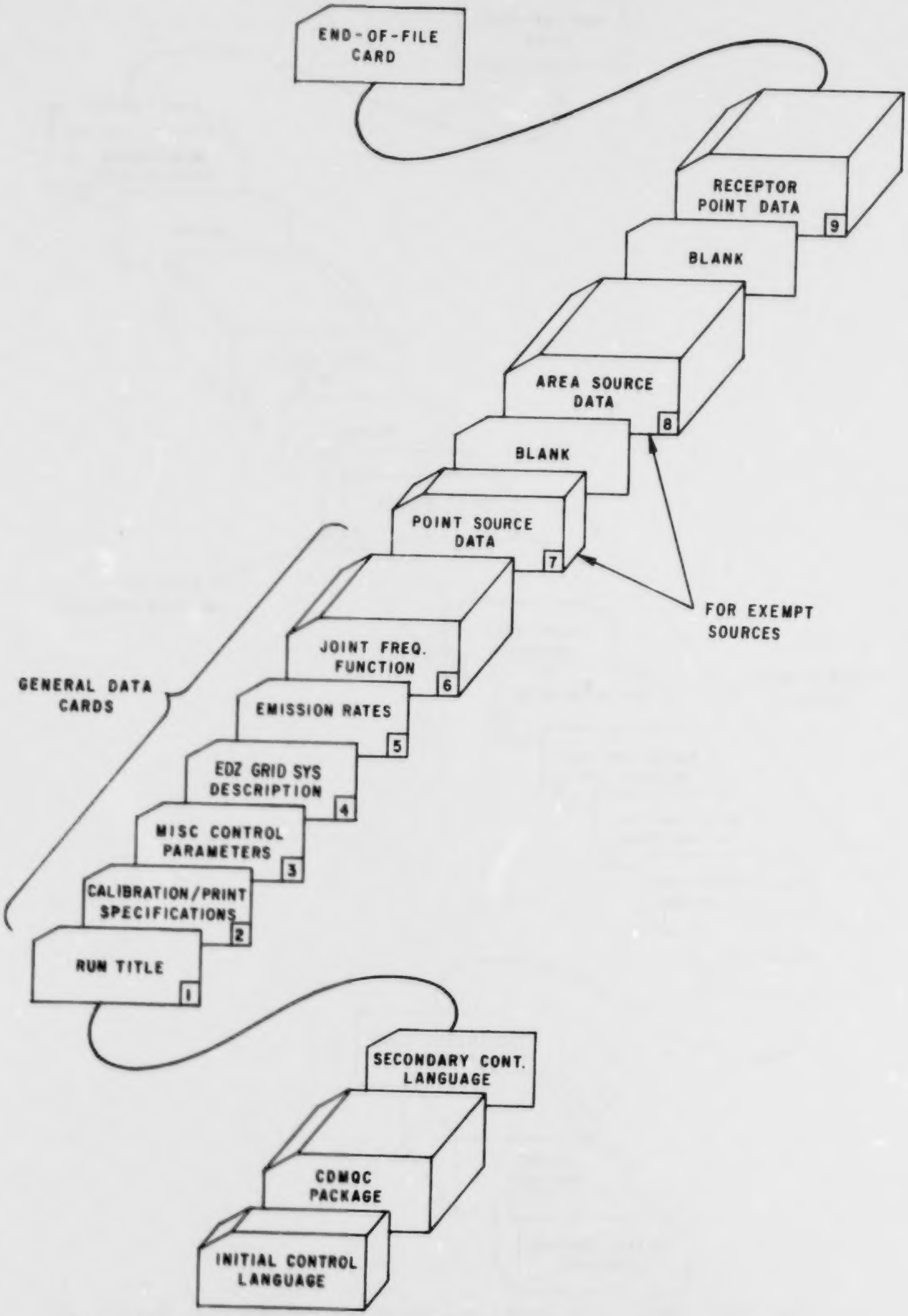

END-OF-FILE CARD
RECEPTOR POINT DATA
9
BLANK
AREA SOURCE DATA
8
BLANK
POINT SOURCE DATA
7
FOR EXEMPT SOURCES
JOINT FREQ. FUNCTION
6
GENERAL DATA CARDS
EMISSION RATES
5
EDZ GRID SYS DESCRIPTION
4
MISC CONTROL PARAMETERS
3
CALIBRATION/PRINT SPECIFICATIONS
2
RUN TITLE
1
SECONDARY CONT. LANGUAGE
CDMQC PACKAGE
INITIAL CONTROL LANGUAGE

Fig. 42. CDMQC Card Input Sequence for Right-Hand-Side Run

Table 13. Summary of the Five CDMQC Runs

LIGHT MANUFACTURING AIR QUALITY RUN

Sources:	All light manufacturing land uses within each of the EDZ grid squares (from Worksheet 2). Stack heights estimated via instructions in Step 8. Each EDZ grid square with a light manufacturing zone is given an emission rate of 10,000 g/s.
Receptors:	All receptors chosen by the procedure used in Step 3.

MEDIUM MANUFACTURING AIR QUALITY RUN

Sources:	All medium manufacturing land uses within each of the EDZ grid squares (from Worksheet 2). Stack heights estimated via instructions in Step 8. Each EDZ grid square with a medium manufacturing zone is given an emission rate of 10,000 g/s.
Receptors:	All receptors chosen by the procedure used in Step 3.

HEAVY MANUFACTURING AIR QUALITY RUN

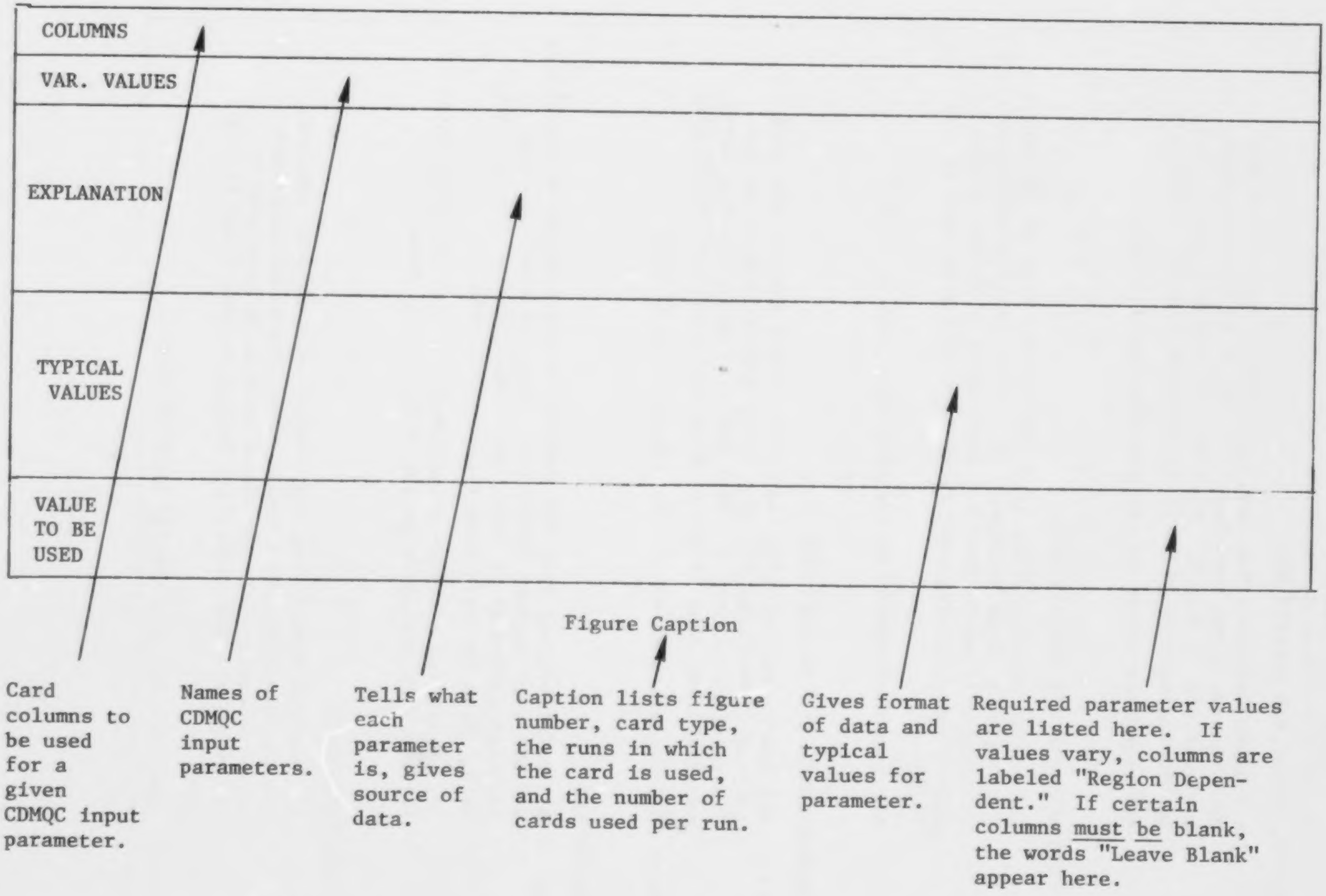
Sources:	All heavy manufacturing land uses within each of EDZ grid squares (from Worksheet 2). Stack heights estimated via instructions in Step 8. Each EDZ grid square with a heavy manufacturing zone is given an emission rate of 10,000 g/s.
Receptors:	All receptors chosen by the procedure in Step 3.

CALIBRATION RUN

Sources:	All point sources from the federal or state emission inventory, and all area sources (subcounty) from the state or local emission inventory or subcounty allocations of federal county data. Data for both from a given past year.
Receptors:	All monitoring stations from federal, state, or local data, for the same past year as the point source data.

RIGHT-HAND-SIDE-RUN

Sources:	All sources exempt from EDZ control such as area sources. The projected emission rates, stack characteristics and other necessary data for these sources is generated by following the EPA Guidelines Series Volumes 7 and 13 and Step 8.
Receptors:	Same as those for the air quality runs.


COLUMNS
VAR. VALUES
EXPLANATION
TYPICAL VALUES
VALUE TO BE USED
Figure Caption

Card columns to be used for a given CDMQC input parameter.

Names of CDMQC input parameters.

Tells what each parameter is, gives source of data.

Caption lists figure number, card type, the runs in which the card is used, and the number of cards used per run.

Gives format of data and typical values for parameter.

Required parameter values are listed here. If values vary, columns are labeled "Region Dependent." If certain columns must be blank, the words "Leave Blank" appear here.

Fig. 43. Layout of CDMQC Card Explanation Pages

run in which the card is to be used. Do not mix cards from one run in with cards from another run.

- There should be a separate file (or box) to hold the cards for each CDMQC run.
- If you have coding and keypunching problems, consult the CDM and CDMQC manuals or contact your EPA regional office (see Fig. 30).

STEP 9A: CODE AND KEYPUNCH GENERAL DATA CARDS (Card Types 1-6)

There are 101 general data cards, and the first five are the most complex cards in the data decks. The contents of these cards are explained in Figs. 44-57. Be sure to note each card's position in the data decks and the run in which it is used.

Type 1 Card. This card titles the output of each of the five runs. Any titles may be used, but each run should be clearly identified.

Type 2 and Type 3 Cards. These cards provide the computer with printing and calibration specifications and miscellaneous control parameters. Note that Columns 1-41 are the same for all Type 2 cards, and Columns 12-80 are the same for all Type 3 cards; the other columns change from run to run.

Type 4 Card. By now you have found that you may have two area source emission grid systems.* The first is the one used in the emissions inventory for subcounty allocations of emissions. The second system is the one produced to define EDZ sources. The emission inventory system will only be used in the calibration run. The EDZ grid system is used in the air quality and right-hand-side runs. Since part of the Type 4 card's function is to describe the grid system, the distinction between the two systems is very important.

Type 5 Card. The decay rates for SO_2 and particulates (Columns 55-66) may vary from region to region. The guidebook assumes very long lifetimes for both pollutants and the same decay rate for both. If you use two different decay rates, two linear program matrices will be required in Step 17 because the transfer coefficients for each pollutant will be different. Having two decay rates will double the number of calculations to be performed in Step 19, and require that two sets of "columns data" cards be keypunched in Step 22.

---

*In some instances these systems will be identical.

Type 6 Cards. These 96 cards contain the Joint Frequency Function data. Single year data are used for the calibration run, while multi-year average data are used for the air quality and right-hand-side runs.

STEP 9B: CODE AND KEYPUNCH POINT SOURCE CARDS (Type 7 Cards)

The point source data cards for the calibration and right-hand-side runs are illustrated in Figs. 58 and 59; no point source cards are used in the air quality runs. Each point source in the emission inventory - to a maximum of 200 point sources* - will have a point source card describing its characteristics. Therefore, there may be 1 to 200 point source cards for each of the two runs. Data for point source cards come from the emission inventory, as modified by the instructions in Step 6, and from Step 8.

All the point source cards will be used in the calibration run. The right-hand-side run will have cards only for point sources that are to be exempt from EDZ (if any). Exempt sources data are optional, as described in Step 7. The one blank card is to be inserted in the data deck after the point source cards to signify the end of the point source data. Only a single blank card will be used in the air quality run in the Type 7 card position.

STEP 9C: CODE AND KEYPUNCH AREA SOURCE CARDS (Type 8 Cards)

There will be five sets of area source cards, one for each CDMQC run. As many as 2500 area source cards may be used per run. The cards are illustrated in Figs. 60-64. The data for these cards have been generated by Steps 2 and 6-8. Step 2's EDZ source data and Step 8's stack height data are used in the three air quality runs. Step 6's emission inventory data are used in the calibration run, with some possibly being used in the right-hand-side run. Step 7's exempt source projections are used in right-hand-side run.

A blank card is inserted in the deck following the area source cards.

STEP 9D: CODE AND KEYPUNCH MONITORING STATION CARDS (Type 9 Cards for Calibration Run)

The data from Worksheet 5 should be transferred to coding forms in the manner shown in Fig. 65. Monitoring station cards are used only in the calibration run. You must have at least three but no more than 50 monitoring stations.*

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*If there are more than 200 point sources in the region, see Appendix I.

STEP 9E: CODE AND KEYPUNCH RECEPTOR POINT CARDS (Type 9 Cards for Air Quality and Right-Hand-Side Runs)

Receptor point cards locate EDZ receptors where the CDMQC program calculates air quality concentrations. The cards, shown in Fig. 66, are used in the air quality and right-hand-side runs. There may be as many as 200 cards per run.*

STEP 9F: MARK AND DUPLICATE CARD DECKS

After keypunching, each CDMQC card deck should be labeled (by writing on the edge of the cards) to keep it organized. Since at least five decks are produced, it is vital to keep the cards separate from each other. A duplicate of each deck should be made as insurance against accidents.

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*If there are more than 50 monitoring stations or 200 receptor points, see Appendix I.

COLUMNS	1-80
VAR. VALUES	ITIT(1) - ITIT(20)
EXPLANATION	ITIT writes a title for the run at the top of each page of output. There should be five different run title cards, one for each run.
TYPICAL VALUES	Select titles that clearly identify the different runs. Suggested titles are: Light Manufacturing Air Quality Run Medium Manufacturing Air Quality Run Heavy Manufacturing Air Quality Run Right-Hand-Side Run Calibration Run
VALUE TO BE USED	For each run, you may write any title you wish provided it starts with a letter of the alphabet and is no more than 80 spaces long.

Fig. 44. Type 1 Card, All Runs: Run Title (one card per run)

COLUMNS	1-4	5-8	9-12	13-16	17-21	22	23-24	25-26	27-31	32-36	37-41	42-50	51-59	60-68	69-77	78-80
VAR. VALUES	AROS1	AROS2	PROS1	PROS2	IRUN	Blank	NLIST1	NLIST2	IRD	IWR	IPU	CA1	CA2	CB1	CB2	Blank
EXPLANATION	These variables are used by advanced users of CDMQC to identify punched output. A name must be supplied, even though it is not used in the guidebook.				Computer run ID number.		Commands printing of JFF data.	Commands printing of point & area source input data.	Data input file number.	Output print file number.	Output punch file number.	A constant to be used for calibration if the user does not want the program to compute calibration coefficients for sulfur dioxide. CA1 and CA2 specify the intercept of the calibration line.	Same as CA1, but for particulates.	Same as CA1, but another constant for sulfur dioxide. CB1 and CB2 specify the slope of the calibration line.	Same as CB1, but for particulates.	
TYPICAL VALUES	A letter/number combination up to four spaces long with the first symbol a letter.				Any value from 00001 to 99999		If NLIST1 or NLIST2 is ≤ 0, the data will be printed. If > 0, no data controlled by NLIST1 or 2 will be printed.		For card input, use 5. Advanced users consult Fortran texts.	For printed paper output, use 6.	For punched card output use 7.	Since no calibration is desired in the air quality and RHS runs, zero is to be used for CA1 and CA2 and one(1) is to be used for CB1 and CB2. Decimal points must be included.				
VALUE TO BE USED	A1	A2	P1	P2	00001	Blank	00	00	00005	00006	00007	0000000.0 for CA1 and CA2.		0000001.0 for CB1 and CB2.		Leave Blank

Fig. 45. Type 2 Card, Air Quality and Right-Hand-Side Runs: Calibration/Print Specifications (one card per run)

COLUMNS	1-4	5-8	9-12	13-16	17-21	22	23-24	25-26	27-31	32-36	37-41	42-80
VAR. VALUES	AROS1	AROS2	PROS1	PROS2	IRUN	Blank	NLIST1	NLIST2	IRD	IWR	IPU	Blank
EXPLANATION	These variables are used by advanced users of CDMQC to identify punched output. A name must be supplied, even though it is not used in the guidebook.				Computer run ID number.		Commands printing of JFF data.	Commands printing of point & area source input data.	Data input file number.	Output print file number.	Output punch file number.	
TYPICAL VALUES	A letter/number combination up to four spaces long with the first symbol a letter.				Any value from 00001 to 99999		If NLIST1 or NLIST2 is ≤ 0, the data will be printed. If > 0, no data controlled by NLIST1 or 2 will be printed.		For card input, use 5. Advanced users consult Fortran texts.	For printed paper output, use 6.	For card punched output, use 7.	
VALUE TO BE USED	A1	A2	P1	P2	00001	Blank	00	00	00005	00006	00007	Leave Blank

Fig. 46. Type 2 Card, Calibration Run: Calibration/Print Specifications (one card per run)

COLUMNS	1-7	8-11	12	13-22	23-32	33	34-37	38	39-42	43-69	70-74	75-80
VAR. VALUES	Blank	IOCAL	Blank	BKGR1	BKGR2	Blank	LPNAM1	Blank	LPNAM2	Blank	CTOF	Blank
EXPLANATION		Indicates calibration option desired.		Background concentrations of the pollutants, if input by the user ($\mu g/m^3$). BKGR1 is for sulfur dioxide and BKGR2 is for particulates.			Abbreviation used for sulfur dioxide.		Abbreviation used for particulates.		CDMQC prints culpability lists that show the origin of pollutants at a receptor. CTOF (cutoff) says that any source contributing less than CTOF% to a receptor will not be included on the list.	
TYPICAL VALUES		Since no calibration is desired, 0000 is used.		Background concentrations will not be input for EDZ. Use all zeros; be sure to include decimal points.			SO2		PART		For EDZ, all sources must be on the lists; therefore 00.00 must be used.	
VALUE TO BE USED	Leave Blank	0000	Blank	00000000.0	00000000.0	Blank	SO2	Blank	PART	Leave Blank	00.00	Leave Blank

Fig. 47. Type 3 Card, Air Quality and Right-Hand-Side Runs: Miscellaneous Control Parameters (one card per run)

COLUMNS	1-6	7	8-11	12	13-22	23-32	33	34-37	38	39-42	43-69	70-74	75-80
VAR. VALUES	NCALR	Blank	IOCAL	Blank	BKGR1	BKGR2	Blank	LPNAM1	Blank	LPNAM2	Blank	CTOF	Blank
EXPLANATION	The total number of monitoring stations used for calibration. NCALR must be ≤ 50.		Indicates the calibration option desired.		Background concentrations of the pollutants, if input by the user ($\mu g/m^3$). BKGR1 is for sulfur dioxide and BKGR2 is for particulates.			Abbreviation used for sulfur dioxide.		Abbreviation used for particulates.		CDMQC prints culpability lists that show the origin of pollutants at a receptor. CTOF (cutoff) says that any source contributing less than CTOF% to a receptor will not be included on the list.	
TYPICAL VALUES	Format 0000XX where XX equals the number of stations.		0003 is to be used in EDZ.		Background concentrations will not be input for EDZ. Use all zeros; be sure to include decimal points.			SO2		PART		For EDZ, all sources must be on the lists; therefore 00.00 must be used.	
VALUE TO BE USED	See above.	Blank	0003	Blank	00000000.0	00000000.0	Blank	SO2	Blank	PART	Leave Blank	00.00	Leave Blank

Fig. 48. Type 3 Card, Calibration Run: Miscellaneous Control Parameters (one card per run)

COLUMNS	1-6	7-12	13-18	19-24	25-30	31-36	37-42	43-60	61-66	67-72	73-80
VAR. VALUES	DELR	RAT	CV	HT	HMIN	XG	YG	Blank	TOA	TXX	Blank
EXPLANATION	Longest distance from any source to any receptor in the EDZ grid system (in m).	Not used in EDZ, but values must be input.		Average annual after-noon mixing height (in m).	Average annual nocturnal or morning mixing height (in m).	UTM easting of the EDZ grid origin (in km).	UTM northing of the EDZ grid origin (in km).		Annual mean atmospheric temperature (in °C).	Length of one side of the smallest EDZ grid square (in m).	
TYPICAL VALUES	A number corresponding to the length of a diagonal of the entire EDZ grid system, taken from Table 2.3 of the CDMQC manual, where "Maximum Range" is the length of the diagonal. Format: XXXX.X	The format is: 000X.0, where X is the length in km of a side of the smallest EDZ grid square.	1000.0	Approximately 0800.0 to 3000.0. See Worksheet 4.	Approximately 0200.0 to 1100.0. See Worksheet 4.	Region Dependent Format: XXXX.X			Approximately -01.11 to 026.67. See Worksheet 4.	Region Dependent Format: XXXX.X	
VALUE TO BE USED	Region Dependent		1000.0	Region Dependent				Leave Blank	Region Dependent		Leave Blank

Fig. 49. Type 4 Card, Air Quality and Right-Hand-Side Runs: EDZ Grid System Description (one card per run)

COLUMNS	1-6	7-12	13-18	19-24	25-30	31-36	37-42	43-60	61-66	67-72	72-80
VAR. VALUES	DELR	RAT	CV	HT	HMIN	XG	YG	Blank	TOA	TXX	Blank
EXPLANATION	Longest distance from any source to any receptor in the emission inventory (in m).	Not used in EDZ, but values must be input.		Average annual after-noon mixing height (in m).	Average annual nocturnal or morning mixing height (in m).	UTM easting of the southwest corner of emission inventory grid system (in km).	UTM northing of the southwest corner of emission inventory grid system (in km).		Annual mean atmospheric temperature (in °C).	Length of one side of the smallest grid square in the emission inventory.	
TYPICAL VALUES	A number corresponding to the length of a diagonal of the entire emission inventory grid system, chosen from Table 2.3 of the CDMQC manual, where "Maximum Range" is the length of the diagonal. Format: XXXX.X	The format is: 000X.0, where X is the length in km of a side of the smallest grid square in the emission inventory.	1000.0	Approximately 0800.0 to 3000.0. See Worksheet 4.	Approximately 0200.0 to 1100.0. See Worksheet 4.	Region Dependent Format: XXXX.X			Approximately -01.11 to 026.67. See Worksheet 4.	Region Dependent Format: XXXX.X	
VALUE TO BE USED	Region Dependent		1000.0	Region Dependent				Leave Blank	Region Dependent		Leave Blank

Fig. 50. Type 4 Card, Calibration Run: Emission Inventory Grid System Description (one card per run)

COLUMNS	1-6	7-12	13-18	19-24	25-30	31-36	37-42	43-48	49-54	55-60	61-66	67-80
VAR. VALUES	DINT	YD	YN	SZA1	SZA2	SZA3	SZA4	SZA5	SZA6	GB1	GB2	Blank
EXPLANATION	Number of intervals used to calculate pollution coming from a 22.5° sector, used in area source calculations.	Ratio of average daytime emission rate to the 24-hour average.	Ratio of average night-time emission rate to the 24-hour average.	SZA1 to SZA6 is the "Vertical Dispersion Function" for each stability class. Generally, all 6 will have the same value.						Decay rate of sulfur dioxide (half-life in hours).	Decay rate of particulates (half-life in hours).	
TYPICAL VALUES	Between 4 and 20. 4 is usually used. If > 4, more accuracy, but higher cost. See CDMQC manual, pages 12 and 39.	Since EDZ is only concerned with maximum emissions, no day/night differences in emission rates will be considered.		Calculated by: SZA = 50-H, where H is the average point source stack height in meters. If H $\geq$ 50, then SZA = 0. No negative values may be used. Format for each SZA value is OXX.XX. Use average stack height for light manufacturing sources.						99999. or less. These may change depending on local conditions; consult the local air pollution control authority.	99999. or less.	
VALUE TO BE USED	0004.0	01.000	01.000	See above.						99999.	99999.	Leave Blank

Fig. 51. Type 5 Card, Light Manufacturing Air Quality Run: Emission Rates (one card per run)

COLUMNS	1-6	7-12	13-18	19-24	25-30	31-36	37-42	43-48	49-54	55-60	61-66	67-80
VAR. VALUES	DINT	YD	YN	SZA1	SZA2	SZA3	SZA4	SZA5	SZA6	GB1	GB2	Blank
EXPLANATION	Number of intervals used to calculate pollution coming from a 22.5° sector, used in area source calculations.	Ratio of average daytime emission rate to the 24-hour average.	Ratio of average nighttime emission rate to the 24-hour average.	SZA1 to SZA6 is the "Vertical Dispersion Function" for each stability class. Generally, all 6 will have the same value.						Decay rate of sulfur dioxide (half-life in hours).	Decay rate of particulates (half-life in hours).	
TYPICAL VALUES	Between 4 and 20. 4 is usually used. If > 4, more accuracy, but higher cost. See CDMQC manual, pages 12 and 39.	Since EDZ is only concerned with maximum emissions, no day/night differences in emission rates will be considered.		Calculated by: SZA = 50-H, where H is the average point source stack height in meters. If H $\geq$ 50, then SZA = 0. No negative values may be used. Format for each SZA value is OXX.XX. Use average stack height for medium manufacturing sources.						99999. or less. These may change depending on local conditions; consult the local air pollution control authority.	99999. or less.	
VALUE TO BE USED	0004.0	01.000	01.000	See above.						99999.	99999.	Leave Blank

Fig. 52. Type 5 Card, Medium Manufacturing Air Quality Run: Emission Rates (one card per run)

COLUMNS	1-6	7-12	13-18	19-24	25-30	31-36	37-42	43-48	49-54	55-60	61-66	67-80
VAR. VALUES	DINT	YD	YN	SZA1	SZA2	SZA3	SZA4	SZA5	SZA6	GB1	GB2	Blank
EXPLANATION	Number of intervals used to calculate pollution coming from a 22.5° sector, used in area source calculations.	Ratio of average daytime emission rate to the 24-hour average.	Ratio of average night-time emission rate to the 24-hour average.	SZA1 to SZA6 is the "Vertical Dispersion Function" for each stability class. Generally, all 6 will have the same value.						Decay rate of sulfur dioxide (half-life in hours).	Decay rate of particulates (half-life in hours).	
TYPICAL VALUES	Between 4 and 20. 4 is usually used. If > 4, more accuracy, but higher cost. See CDMQC manual, pages 12 and 39.	Since EDZ is only concerned with maximum emissions, no day/night differences in emission rates will be considered.		Calculated by: SZA = 50-H, where H is the average point source stack height in meters. If H $\geq$ 50, then SZA = 0. No negative values may be used. Format for each SZA value is OXX.XX. Use average stack height for heavy manufacturing sources.						99999. or less. These may change depending on local conditions; consult the local air pollution control authority.	99999. or less.	
VALUE TO BE USED	0004.0	01.000	01.000	See above.						99999.	99999.	Leave Blank

Fig. 53. Type 5 Card, Heavy Manufacturing Air Quality Run: Emission Rates (one card per run)

COLUMNS	1-6	7-12	13-18	19-24	25-30	31-36	37-42	43-48	49-54	55-60	61-66	67-80
VAR. VALUES	DINT	YD	YN	SZA1	SZA2	SZA3	SZA4	SZA5	SZA6	GB1	GB2	Blank
EXPLANATION	Number of intervals used to calculate pollution coming from a 22.5° sector, used in area source calculations.	Ratio of average daytime emission rate to the 24-hour average.	Ratio of average night-time emission rate to the 24-hour average.	SZA1 to SZA6 is the "Vertical Dispersion Function" for each stability class. Generally, all 6 will have the same value.						Decay rate of sulfur dioxide (half-life in hours).	Decay rate of particulates (half-life in hours).	
TYPICAL VALUES	Between 4 and 20. 4 is usually used. If > 4, more accuracy, but higher cost. See CDMQC manual, pages 12 and 39.	Since EDZ is only concerned with maximum emissions, no day/night differences in emission rates will be considered.		Calculated by: SZA = 50-H, where H is the average point source stack height in meters. If $H \geq 50$, then SZA = 0. No negative values may be used. Format for each SZA value is 0XX.XX. Use average stack height for all existing sources.						99999. or less. These may change depending on local conditions; consult the local air pollution control authority.	99999. or less.	
VALUE TO BE USED	0004.0	01.000	01.000	See above.						99999.	99999.	Leave Blank

Fig. 54. Type 5 Card. Calibration Run: Emission Rates (one card per run)

COLUMNS	1-6	7-12	13-18	19-24	25-30	31-36	37-42	43-48	49-54	55-60	61-66	67-80
VAR. VALUES	DINT	YD	YN	SZA1	SZA2	SZA3	SZA4	SZA5	SZA6	GB1	GB2	Blank
EXPLANATION	Number of intervals used to calculate pollution coming from a 22.5° sector, used in area source calculations.	Ratio of average daytime emission rate to the 24-hour average.	Ratio of average night-time emission rate to the 24-hour average.	SZA1 to SZA6 is the "Vertical Dispersion Function" for each stability class. Generally, all 6 will have the same value.						Decay rate of sulfur dioxide (half-life in hours).	Decay rate of particulates (half-life in hours).	
TYPICAL VALUES	Between 4 and 20. 4 is usually used. If > 4, more accuracy, but higher cost. See CDMQC manual, pages 12 and 39.	Since EDZ is only concerned with maximum emissions, no day/night differences in emission rates will be considered.		Calculated by: SZA = 50-H, where H is the average point source stack height in meters. If H $\geq$ 50, then SZA = 0. No negative values may be used. Format for each SZA value is OXX.XX. Use estimated stack height; see Step 8.						99999. or less. These may change depending on local conditions; consult the local air pollution control authority.	99999. or less.	
VALUE TO BE USED	0004.0	01.000	01.000	See above.						99999.	99999.	Leave Blank

Fig. 55. Type 5 Card, Right-Hand-Side Run: Emission Rates (one card per run)

COLUMNS	1-7	8-14	15-21	22-28	29-35	36-42	43-49	50-80
EXPLANATION	Blank	JFF percentage for Wind Speed Class 1.	JFF percentage for Wind Speed Class 2.	JFF percentage for Wind Speed Class 3.	JFF percentage for Wind Speed Class 4.	JFF percentage for Wind Speed Class 5.	JFF percentage for Wind Speed Class 6.	Blank
		These six percentages are for one stability class/wind sector combination. There is one card for each such combination: 16 cards (one for each of the 16 different wind sectors) for Stability Class 1, 16 cards for Stability Class 2, etc., for a total of 96 cards for the six stability classes. For the air quality and RHS runs, use percentages which represent an average JFF for a number of years.						
TYPICAL VALUES		Region Dependent. Format for each percentage: X.XXXXX						
VALUE TO BE USED	Leave Blank	Region Dependent						Leave Blank

If you receive cards from the Day-Night STAR program, insert them as they are. If you must type cards based on Day-Night STAR printed output, follow the format shown above. For data in formats other than Day-Night STAR, consult the CDM and CDMQC manuals.

Fig. 56. Type 6 Cards, Air Quality and Right-Hand-Side Runs: Joint Frequency Function (one set of 96 cards per run)

COLUMNS	1-7	8-14	15-21	22-28	29-35	36-42	43-49	50-80
EXPLANATION	Blank	JFF percentage for Wind Speed Class 1.	JFF percentage for Wind Speed Class 2.	JFF percentage for Wind Speed Class 3.	JFF percentage for Wind Speed Class 4.	JFF percentage for Wind Speed Class 5.	JFF percentage for Wind Speed Class 6.	Blank
		These six percentages are for one stability class/wind sector combination. There is one card for each such combination: 16 cards (one for each of the 16 different wind sectors) for Stability Class 1, 16 cards for Stability Class 2, etc., for a total of 96 cards for the six stability classes. For the calibration run, use JFF data for one year. The year selected should be the same as the year in which the monitoring station data were collected.						
TYPICAL VALUES		Region Dependent. Format for each percentage: X.XXXXX						
VALUE TO BE USED	Leave Blank	Region Dependent						Leave Blank

If you receive cards from the Day-Night STAR program, insert them as they are. If you must type cards based on Day-Night STAR printed output, follow the format shown above. For data in formats other than Day-Night STAR, consult the CDM and CDMQC manuals.

Fig. 57. Type 6 Cards, Calibration Run: Joint Frequency Function (one set of 96 cards per run)

COLUMNS	1-6	7-13	14-20	21-28	29-36	37-43	44-48	49-55	56-62	63-67	68-72	73-80
VAR. VALUES	X	Y	Blank	S1	S2	SH	D	VS	T	Blank	PSNAM	Blank
EXPLANATION	Normalized UTM easting of the point source (in km).	Normalized UTM northing of the point source (in km).		Source emission rate for sulfur dioxide (in g/s).	Source emission rate for particulates (in g/s).	Stack height (in m).	Stack diameter (in m).	Stack gas exit velocity (in m/s);	Stack gas temperature (in °C).		Optional five character identifier of the point source. May be left blank if desired.	
				Data obtained from emission inventory.								
TYPICAL VALUES	Source Dependent			Source Dependent							Any 5 digits/letters may be used, but may not be the same as IDs used on area source, monitoring station, or receptor point cards.	
	Format: XXXX.X	Format: XXXXX.X		Format: XXX.XXXX If no sulfur dioxide is emitted, use 000.0000	Format: XXX.XXXX If no particulates are emitted, use 000.0000	Format: XXX.XXX	Format: XX.XX	Format: XX.XXXX	Format: XXX.XXX			
VALUE TO BE USED	Source Dependent		Leave Blank	Source Dependent						Leave Blank	See above.	Leave Blank

Fig. 58. Type 7 Cards, Calibration Run: Point Source Data (one card for each source in the emission inventory; maximum of 200 cards)

COLUMNS	1-6	7-13	14-20	21-28	29-36	37-43	44-48	49-55	56-62	63-67	68-72	73-80
VAR. VALUES	X	Y	Blank	S1	S2	SH	D	VS	T	Blank	PSNAM	Blank
EXPLANATION	Normalized UTM easting of the point source (in km).	Normalized UTM northing of the point source (in km).		Source emission rate for sulfur dioxide (in g/s). Use projected emissions.	Source emission rate for parti-culates (in g/s).	Stack height (in m). See Step 8 for guidance on data to be used.	Stack diameter (in m).	Stack gas exit velocity (in m/s).	Stack gas temperature (in °C),		Optional five character identifier of the point source. May be left blank if desired.	
TYPICAL VALUES	Source Dependent Format: XXXX.X	Format: XXXXX.X		Source Dependent Format: XXX.XXXX If no sulfur dioxide is emitted, use 000.0000	Format: XXX.XXXX If no particu-lates are emitted, use 000.0000	Format: XXX.XXX	Format: XX.XX	Format: XX.XXXX	Format: XXX.XXX		Any 5 digits/letters may be used, but may not be the same as IDs used on area source, monitoring station, or receptor point cards.	
VALUE TO BE USED	Source Dependent		Leave Blank	Source Dependent						Leave Blank	See above.	Leave Blank

Fig. 59. Type 7 Cards, Right-Hand-Side Run: Point Source Data (one card for each exempt point source; maximum of 200 cards)

COLUMNS	1-6	7-13	14-20	21-28	29-36	37-43	44-48	49-80
VAR. VALUES	X	Y	TX	S1	S2	SH	ASNAM	Blank
EXPLANATION	Normalized UTM easting of the southwest corner of one EDZ grid square (in km).	Normalized UTM northing of the southwest corner of one EDZ grid square (in km).	Width of the grid square (in m).	The grid square's area source emission rate for sulfur dioxide (in g/s).	The grid square's area source emission rate for particulates (in g/s).	Estimated average stack height within the square for light manufacturing uses only (in m).	Optional grid square identifying number. May be left blank if desired.	
TYPICAL VALUES	These are the UTM coordinates for each EDZ grid square generated in Step 2. Format: XXXX.X	Format: XXXXX.X	01000.0, 02000.0, 04000.0, 08000.0, 16000.0, or other depending on the square. Format: XXXXX.X	The emission rates for the air quality runs are set unusually high to assure that the emissions from each area source to each receptor are modeled. The high rates are adjusted in the linear program's transfer coefficients. Use 10,000 g/s.		See Step 8. Format: XXX.XXX	00001 to 02500	
VALUE TO BE USED	Region Dependent			10000.00	10000.00	Region Dependent		Leave Blank

Fig. 60. Type 8 Cards, Light Manufacturing Air Quality Run: Area Source Data (one card for each EDZ grid square with light manufacturing; maximum of 2500 cards)

COLUMNS	1-6	7-13	14-20	21-28	29-36	37-43	44-48	49-80
VAR. VALUES	X	Y	TX	S1	S2	SH	ASNAM	Blank
EXPLANATION	Normalized UTM easting of the southwest corner of one EDZ grid square (in km).	Normalized UTM northing of the southwest corner of one EDZ grid square (in km).	Width of the grid square (in m).	The grid square's area source emission rate for sulfur dioxide (in g/s).	The grid square's area source emission rate for particulates (in g/s).	Estimated average stack height within the square for medium manufacturing uses only (in m).	Optional grid square identifying number. May be left blank if desired.	
TYPICAL VALUES	These are the UTM coordinates for each EDZ grid square generated in Step 2. Format: XXXX.X	Format: XXXXX.X	01000.0, 02000.0, 04000.0, 08000.0, 16000.0, or other depending on the square. Format: XXXXX.X	The emission rates for the air quality runs are set unusually high to assure that the emissions from each area source to each receptor are modeled. The high rates are adjusted in the linear program's transfer coefficients. Use 10,000 g/s.		See Step 8. Format: XXX.XXX	00001 to 02500	
VALUE TO BE USED	Region Dependent			10000.00	10000.00	Region Dependent		Leave Blank

Fig. 61. Type 8 Cards, Medium Manufacturing Air Quality Run: Area Source Data (one card for each EDZ grid square with medium manufacturing; maximum of 2500 cards)

COLUMNS	1-6	7-13	14-20	21-28	29-36	37-43	44-48	49-80
VAR. VALUES	X	Y	TX	S1	S2	SH	ASNAM	Blank
EXPLANATION	Normalized UTM easting of the southwest corner of one EDZ grid square (in km).	Normalized UTM northing of the southwest corner of one EDZ grid square (in km).	Width of the grid square (in m).	The grid square's area source emission rate for sulfur dioxide (in g/s).	The grid square's area source emission rate for particulates (in g/s).	Estimated average stack height within the square for heavy manufacturing uses only (in m).	Optional grid square identifying number. May be left blank if desired.	
TYPICAL VALUES	These are the UTM coordinates for each EDZ grid square generated in Step 2. Format: XXXX.X	Format: XXXXX.X	01000.0, 02000.0, 04000.0, 08000.0, 16000.0, or other depending on the square. Format: XXXXX.X	The emission rates for the air quality runs are set unusually high to assure that the emissions from each area source to each receptor are modeled. The high rates are adjusted in the linear program's transfer coefficients. Use 10,000 g/s.		See Step 8. Format: XXX.XXX	00001 to 02500	
VALUE TO BE USED	Region Dependent			10000.00	10000.00	Region Dependent		Leave Blank

Fig. 62. Type 8 Cards, Heavy Manufacturing Air Quality Run: Area Source Data (one card for each EDZ grid square with heavy manufacturing; maximum of 2500 cards)

COLUMNS	1-6	7-13	14-20	21-28	29-36	37-43	44-48	49-80
VAR. VALUES	X	Y	TX	S1	S2	SH	ASNAM	Blank
EXPLANATION	Normalized UTM easting of the southwest corner of one emission inventory grid square (in km).	Normalized UTM northing of the southwest corner of one emission inventory grid square (in km).	Width of the emission inventory square (in m).	The emission inventory grid square's (area source) emission rate for sulfur dioxide (in g/s). If none use 0000.000	The emission inventory grid square's emission rate for particulates (in g/s). If none use 0000.000	Average stack height within the square (in m).	Optional grid square (area source) identifying number. May be left blank if desired.	
TYPICAL VALUES	Depends on Square Format: XXX.XX	Format: XXXX.XX	Format: XXXXX.X	From Emission Inventory Format: XXXX.XXX	Format: XXXX.XXX	Format: XXX.XXX	Format: XXXXX	
VALUE TO BE USED	Region Dependent							Leave Blank

Fig. 63. Type 8 Cards, Calibration Run: Area Source Data (one card for each emission inventory grid square; maximum of 2500 cards)

COLUMNS	1-6	7-13	14-20	21-28	29-36	37-43	44-48	49-80
VAR. VALUES	X	Y	TX	S1	S2	SH	ASNAM	Blank
EXPLANATION	Normalized UTM easting of the southwest corner of one emission inventory grid square (in km)	Normalized UTM northing of the southwest corner of one emission inventory grid square (in km).	Width of the emission inventory square (in m).	Projected emission inventory grid square (area source) emission rate for sulfur dioxide (in g/s).	Projected emission inventory grid square (area source) emission rate for parti-culates (in g/s).	Projected average stack height within the square (in m).	Optional grid square (area source) identifying number. May be left blank if desired.	
TYPICAL VALUES	Depends on square			See Steps 7 and 8			Taken from emission inventory	
	Format: XXX.XX	Format: XXXX.XX	Format: XXXXX.X	Format: XXXX.XXX	Format: XXXX.XXX	Format: XXX.XXX	Format: XXXXX	
VALUE TO BE USED	Region Dependent							Leave Blank

Fig. 64. Type 8 Cards, Right-Hand-Side Run: Area Source Data (one card for each exempt area source; maximum of 2500 cards)

COLUMNS	1-8	9-16	17-29	30-35	36-41	42-53	54-55	56-57	58-59	60-61	62-76	77-80
VAR. VALUES	RX	RY	Blank	COBS1	COBS2	Blank	IPNCH	NROSE	NCULP	NLARS	Blank	NRAM
EXPLANATION	Normalized UTM easting of the monitoring station (in km)	Normalized UTM northing of the monitoring station (in km)		Measured concentration of pollutant, annual arithmetic mean (in $\mu g/m^3$). COBS1 is for sulfur dioxide.	COBS2 is for particulates.		Not used in EDZ, but a value must be input.	Tells computer if concentration roses are to be printed.	Tells computer if source contribution lists are to be printed.	Not used in EDZ, but a value must be input.		Four digit identifying number.
TYPICAL VALUES	Region Dependent Format: XXXX.XXX	Format: XXXX.XXX		Format: XXXX.X	Format: XXXX.X		00 required for EDZ.	00 required for EDZ.	03 provides source contribution lists.	00 required for EDZ.		Format: XXXX
VALUE TO BE USED	Region Dependent		Leave Blank	Region Dependent		Leave Blank	00	00	03	00	Leave Blank	At user's discretion

Fig. 65. Type 9 Cards, Calibration Run: Monitoring Station Data (one card for each monitoring station; maximum of 50 cards)

COLUMNS	1-8	9-16	17-53	54-55	56-57	58-59	60-61	62-76	77-80
VAR. VALUES	RX	RY	Blank	IPNCH	NROSE	NCULP	NLARS	Blank	NRAM
EXPLANATION	Normalized UTM easting of the receptor point (in km).	Normalized UTM northing or the receptor point (in km).		Not used in EDZ, but a value must be input.	Tells computer if concentration roses are to be printed.	Tells computer if source contribution lists are to be printed.	Not used in EDZ, but a value must be input.		Four digit identifying number
TYPICAL VALUES	Region Dependent Format: XXXX.XXX	Format: XXXX.XXX		00 required for EDZ.	00 required for EDZ.	03 provides source contribution lists.	00 required for EDZ.		Format: XXXX
VALUE TO BE USED	Region Dependent		Leave Blank	00	00	03	00	Leave Blank	At user's discretion.

Fig. 66. Type 9 Cards, Air Quality and Right-Hand-Side Runs: Receptor Point Data (one card for each receptor point; maximum of 200 cards)

STEP 10: ACQUIRE DISPERSION MODEL

SUMMARY

Step 10 is the acquisition of the atmospheric dispersion model used to calculate air quality.

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

Only the prerequisites outlined in the Introduction must be fulfilled, as shown in Fig. 67. Personnel requirements are listed in Table 14.

ACQUIRE DISPERSION MODEL

The Climatological Dispersion Model, version CDMQC, is recommended for use in establishing emission density limits. Another dispersion model can be used provided it: (1) can estimate annual average concentrations of sulfur dioxide and particulate matter, and (2) can estimate the annual average sulfur dioxide and particulate matter concentrations at each receptor caused by each source, that is, can estimate each source's contribution to the pollution level at each receptor. (If you are using AQDM, see Appendix G.)

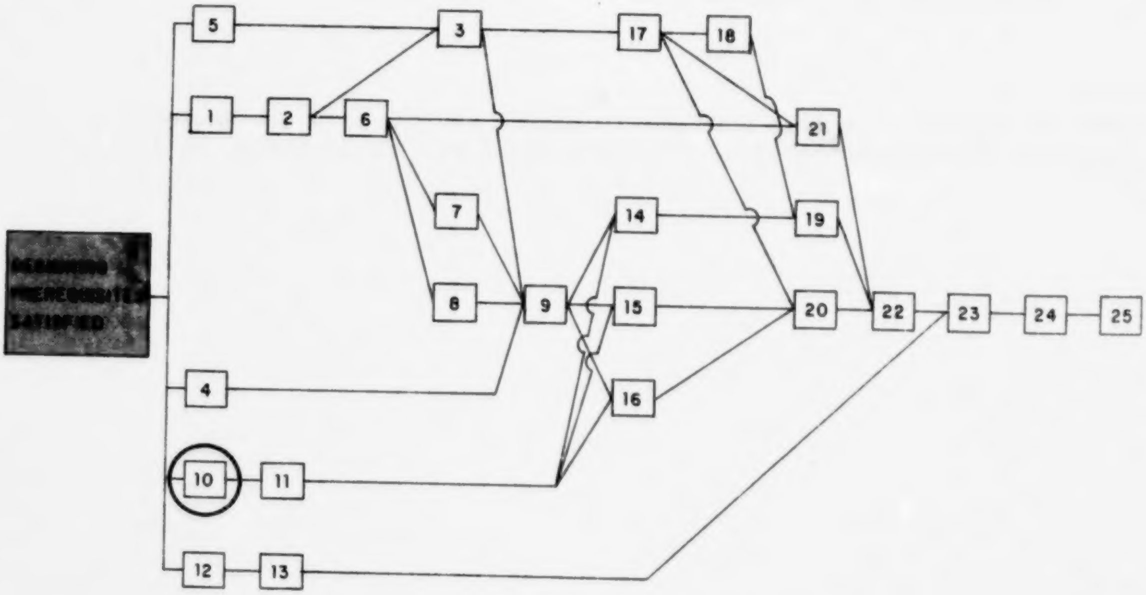

Fig. 67. Prerequisites for Step 10

Table 14. Resource Requirements for Step 10

Necessary Skills	Necessary Data	Necessary Hardware
Computer Programming	None	None

The CDMQC program is available on cards from:*

Modeling Support Section, Mail Drop 14
Source-Receptor Analysis Branch, Monitoring Data and Analysis Div.
Office of Air Quality Planning and Standards
Environmental Protection Agency
Research Triangle Park, NC 27711

About one to three weeks are required for delivery. In addition to requesting the CDMQC program deck, you should ask for the CDM and CDMQC manuals listed below:

Busse, A.D., and J.R. Zimmerman, *User's Guide for the Climatological Dispersion Model,* U.S. EPA Report EPA-R4-73-024, NTIS No. PB-227-346 (Dec. 1973).

Brubaker, K.L., P. Brown, and R.R. Cirillo, *Addendum to the User's Guide for the Climatological Dispersion Model,* U.S. EPA Report No. EPA-450/3-77-015 (July 1977).

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*CDMQC is available on tape through the UNIMAP system, from the National Technical Information Service, 5285 Port Royal Rd., Springfield, VA 22161.

STEP 11: INSTALL DISPERSION MODEL ON COMPUTER AND CHECK

SUMMARY

In Step 11 the dispersion model is checked to make sure it operates properly. Of the three substeps listed below, the first applies to any dispersion model, while the next two are specific to CDMQC:

Step 11A: Install Dispersion Model on Computer
Step 11B: Secure and Keypunch Test Data for CDMQC
Step 11C: Run CDMQC Test Example and Check Results

If you are not using CDMQC, consult the users manual for your dispersion model for steps similar to 11B and 11C.

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

Step 10 must be completed --that is, you must have the dispersion model program and manuals -- before beginning Step 11, as shown in Fig. 68. The major resource required for Step 11 is a computer. Step 11 is best handled by a programmer. Resource requirements are shown in Table 15.

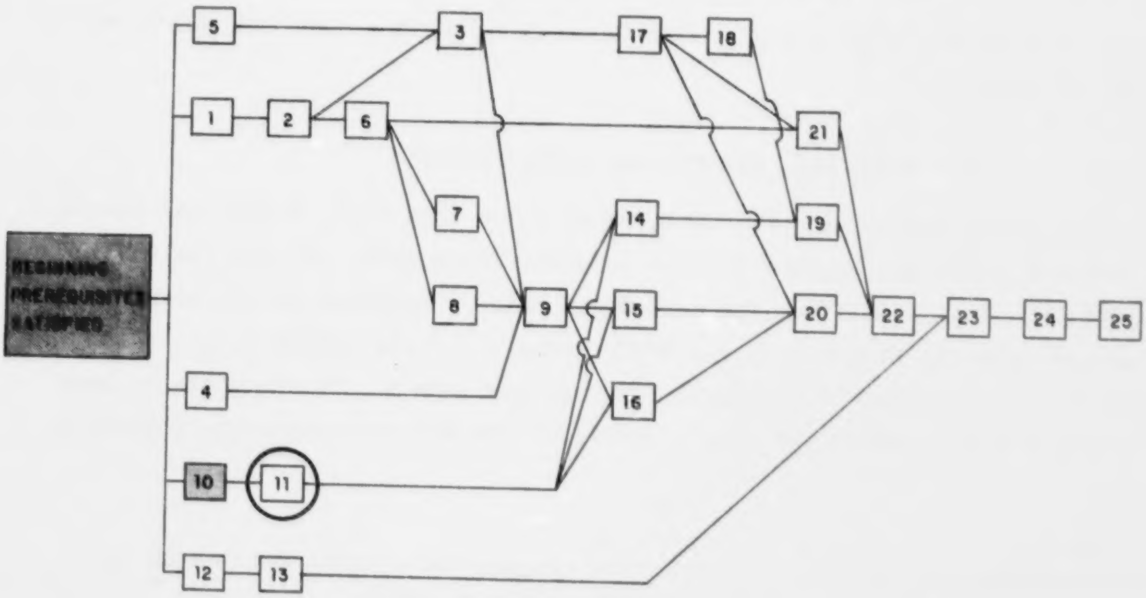

Fig. 68. Prerequisites for Step 11

Table 15. Resource Requirements for Step 11

Necessary Skills	Necessary Data	Data Sources	Necessary Hardware
Computer Programming	CDMQC (or other dispersion model) Program	Step 10	Computer with Fortran G or H compiler (or computer with appropriate equipment for the dispersion model being used).
	CDM and CDMQC (or other dispersion model) Manuals	Step 10	

STEP 11A: INSTALL DISPERSION MODEL ON COMPUTER*

Installation of the dispersion model acquired in Step 10 is entirely dependent on the model and the hardware being used. In all cases, installation must be handled by a programmer familiar with the computer system.

STEP 11B: SECURE AND KEYPUNCH TEST DATA FOR CDMQC

The sample problem in the CDMQC manual, *Addendum to the User's Guide for the Climatological Dispersion Model*, should be used to test the CDMQC package. The input data will be the "TEST CITY Input Data Set" shown in Fig. C.2 in the CDMQC manual. Format instructions are provided in the manual and in Step 9.

STEP 11C: RUN CDMQC TEST EXAMPLE AND CHECK RESULTS

After keypunching the data, prepare the card deck, insert the control language cards appropriate for the computer being used, and run the test problem. The output from the test run should be compared to the sample output shown in Fig. C.3 of the CDMQC manual. If the values do not match check the input data and control language for errors. If there are no keypunch errors, consult the user's manual or the EPA Modeling Support Section.

---

*A decision must be made on whether to execute the program from cards or disk; a disk is easier to handle than a deck of cards. Procedures for transferring programs from cards to disk vary from computer center to computer center; consult a programmer familiar with the installation being used if you want to use a disk. The program may be transferred to disk as a load module, which eliminates the compiling step and saves time. For simplicity, this guidebook assumes the dispersion model program is on cards.

STEP 12: ACQUIRE LINEAR PROGRAMMING PACKAGE

SUMMARY

Step 12 is the acquisition of a linear programming package suitable for use in setting emission density limits. Two substeps are involved:

Step 12A: Select a Linear Programming Package
Step 12B: Acquire the Package

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

Only the prerequisites discussed in the Introduction must be satisfied, as shown in Fig. 69. Personnel and information needs are listed in Table 16.

STEP 12A: SELECT A LINEAR PROGRAMMING PACKAGE

Linear programming systems are very similar to one another; they all use comparable equations and assumptions.

IBM's Mathematical Programming System - Extended (MPSX) is recommended for use because it has all the required features for EDZ and is readily available from IBM. However, MPSX may not be usable for all regions implementing EDZ because it can only be used on an IBM 360 or 370 computer. While the

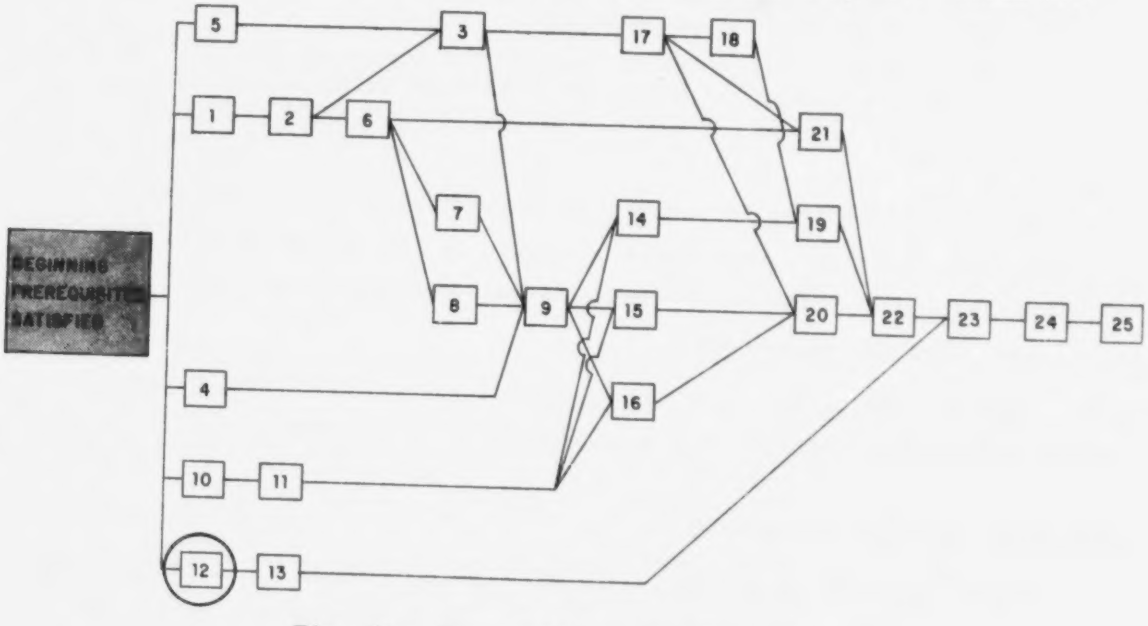

Fig. 69. Prerequisites for Step 12

Table 16. Resource Requirements for Step 12

Necessary Skills[a]	Necessary Data	Data Sources	Necessary Hardware
Computer Programming Secretarial	Knowledge of computer being used	Local	None

[a] First on list directs this step.

guidebook assumes the use of MPSX, the data processing steps are basically the same for all linear programming packages.

Other computer companies and software houses have their own linear programming packages. Appendix H discusses some of the available linear programming systems. The linear programming package selected for use in EDZ must be able to efficiently handle a "large" problem with a nearly 100% dense coefficient matrix. A "large" problem is one which involves x columns and y rows, where:

x = a number somewhat smaller than the number of EDZ grid squares covering your region times the number of simplified land use classes (see Step 2). If the guidebook methodology is followed, x will be less than or equal to 1,050 (this means there will be as many as 1,050 columns in the linear programming coefficient matrix).

y = the number of receptors in your region (see Step 3). In most cases y will be about 200 (200 rows in the coefficient matrix), but there will be great variability from region to region.

MPSX has provisions for upper and lower bounds; if the package you use does not, the bound constraints discussed in the guidebook will have to be converted into two inequality constraints, consistent with the format of the linear programming package.

Consult with personnel at your computer center to determine which linear programming package is most appropriate for your use.

STEP 12B: ACQUIRE THE PACKAGE

First, contact the personnel at the computer center you will be using and see if a suitable linear programming system is available. If so, inquire about control language and manuals explaining data inputs, and go on to Step 13. If not, ask about the feasibility of acquiring an outside package and using it on the computer center's hardware.

If possible, you should contact representatives of the hardware manufacturer about acquiring a package and the appropriate supporting information. If you are going to use MPSX, obtain IBM Publication No. 5734-XM4, the MPSX manual: *Mathematical Programming System-Extended (MPSX) and Generalized Upper Boundary (GUB) Program Description*. When the materials arrive, Step 13 may be begun.

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STEP 13: INSTALL LINEAR PROGRAMMING PACKAGE ON COMPUTER AND CHECK

SUMMARY

In Step 13 the linear programming package is checked to make sure it operates properly. Of the three substeps listed below, the first applies to any such package, while the next two are specific to MPSX:

Step 13A: Install Linear Programming Package on Computer
Step 13B: Secure and Keypunch Test Data for MPSX
Step 13C: Run MPSX Test Example and Check Results

If you are not using MPSX, consult the users manual for your linear programming package for steps similar to 13B and 13C.

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

Step 12 must be completed -- that is, you must have the linear programming package and users manual -- before beginning Step 13, as shown in Fig. 70. Resource requirements are listed in Table 17. Step 13 is best handled by a programmer.

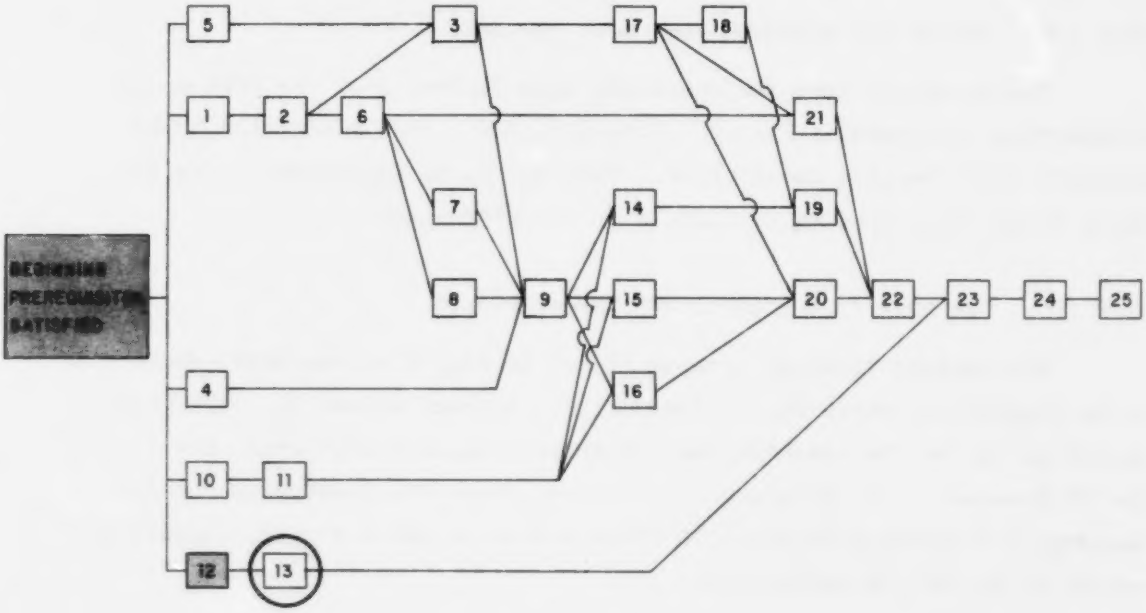

Fig. 70. Prerequisites for Step 13

Table 17. Resource Requirements for Step 13

Necessary Skills	Necessary Data	Data Sources	Necessary Hardware
Computer Programming	Linear Programming Package (MPSX or other)	Step 12	Computer, Reader/Printer, etc. required for the particular program. If you are using MPSX: • IBM 360 or 370 computer • Minimum 86K region • Printer with $\geq$ 132 positions • Magnetic tape unit, 2400 or 3400 series • Eight cylinders space on a 2314 direct access device

STEP 13A: INSTALL LINEAR PROGRAMMING PACKAGE ON COMPUTER

Installation of the linear programming package acquired in Step 12 is entirely dependent on the package and the hardware being used. In all cases, installation must be handled by a programmer familiar with the computer system.

STEP 13B: SECURE AND KEYPUNCH TEST DATA FOR MPSX

The necessary data are available from Chapter 2 of the MPSX manual, *Mathematical Programming System - Extended (MPSX) and Generalized Upper Boundary (GUB) Program Description*. They are to be keypunched using the input format described in Appendix A of the MPSX manual.

STEP 13C: RUN MPSX TEST EXAMPLE AND CHECK RESULTS

The control language program (found in Fig. 3 of the MPSX manual) is to be keypunched, starting all instructions in card column 10. The package should be run on the computer and the output compared with Figs. 8 - 14 of the MPSX manual. If there are differences, check the input data and control language for keypunch errors. If there are no keypunch errors, consult the manual or an IBM representative.

STEP 14: MAKE AIR QUALITY DISPERSION MODEL RUNS*

SUMMARY

In Step 14 you make the three air quality runs of CDMQC: for light manufacturing, medium manufacturing, and heavy manufacturing sources. The substeps involved are:

Step 18A: Verify Input Sequence for Each Run
Step 18B: Insert Control Language and Run Program
Step 18C: Check Results

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

The cards for the three air quality runs must have been keypunched and checked for accuracy (Step 9) before you begin Step 14. The CDMQC program acquired in Step 10 also must have been tested as described in Step 11. The position of Step 14 in the EDZ methodology is shown in Fig. 71. The resources required for this step are listed in Table 18.

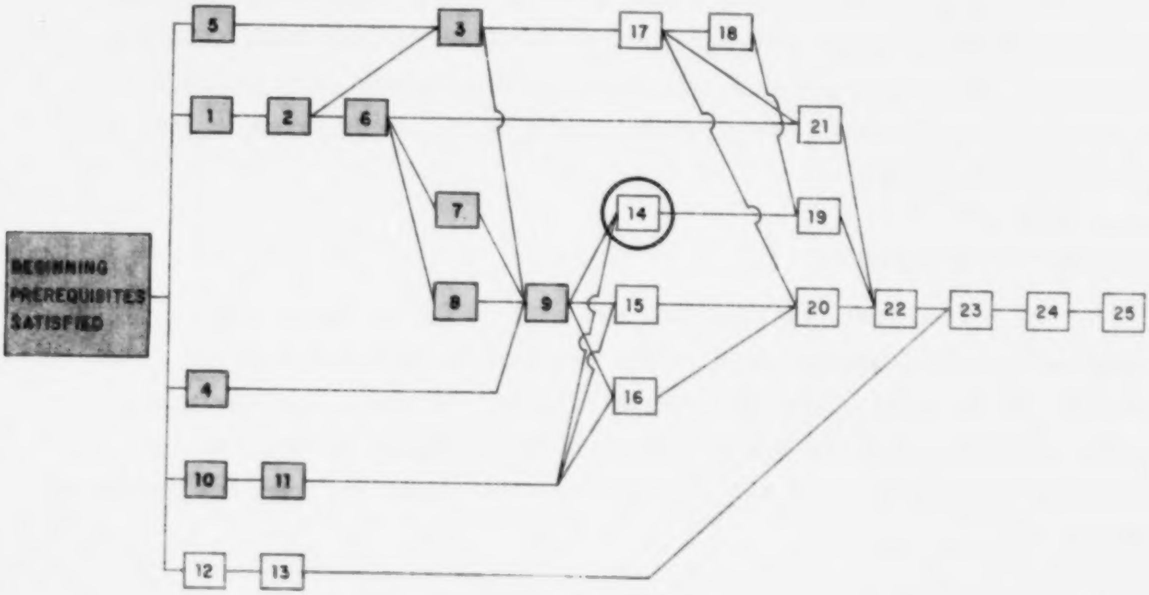

Fig. 71. Prerequisites for Step 14

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*This discussion applies specifically to CDMQC; if you are using another dispersion model, consult your users manual.

Table 18. Resource Requirements for Step 14

Necessary Skills[a]	Necessary Data	Data Sources	Necessary Hardware
Programming Data Analysis	Keypunched Data	Step 9	Computer with a Fortran G or H compiler
	CDMQC Program	Step 11	

[a] First on list directs this step.

STEP 18A: VERIFY INPUT SEQUENCE FOR EACH RUN

The input sequence for the cards in each of the air quality runs was illustrated in Fig. 40 on pg. 94. Be sure (1) the cards are in the exact order shown (or the program will not work) and (2) the proper area source cards are in each deck (for example, only the light manufacturing area source cards are in the light manufacturing run deck.)

STEP 18B: INSERT CONTROL LANGUAGE AND RUN PROGRAM

The control language for CDMQC will vary from computer to computer. Personnel trained in the operation of the computer you are using should be consulted. It may be possible that the control language from the test case of Step 11 can be used. The programs should be run using an equivalent computer region of 250K.

STEP 18C: CHECK RESULTS

The printed outputs from each run will be fairly long. They should be compared with the example CDMQC output provided in Appendix C of the CDMQC manual. If they are comparable, go to Step 15. If there are discrepancies, retrace earlier steps to see if the error can be found. Be sure to have a qualified programmer check the system completion codes and look for execution errors.

STEP 15: MAKE CALIBRATION DISPERSION MODEL RUN*

SUMMARY

In Step 15 you make the calibration run of CDMQC. Three substeps are involved:

Step 15A: Verify Input Sequence for Each Run
Step 15B: Insert Control Language and Run Program
Step 15C: Check Results

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

Before you begin Step 15, the calibration run cards must have been keypunched and checked for accuracy (Step 9). The CDMQC program acquired in Step 10 also must have been tested as described in Step 11. The position of Step 15 in the EDZ methodology is shown in Fig. 72. Resources required are listed in Table 19.

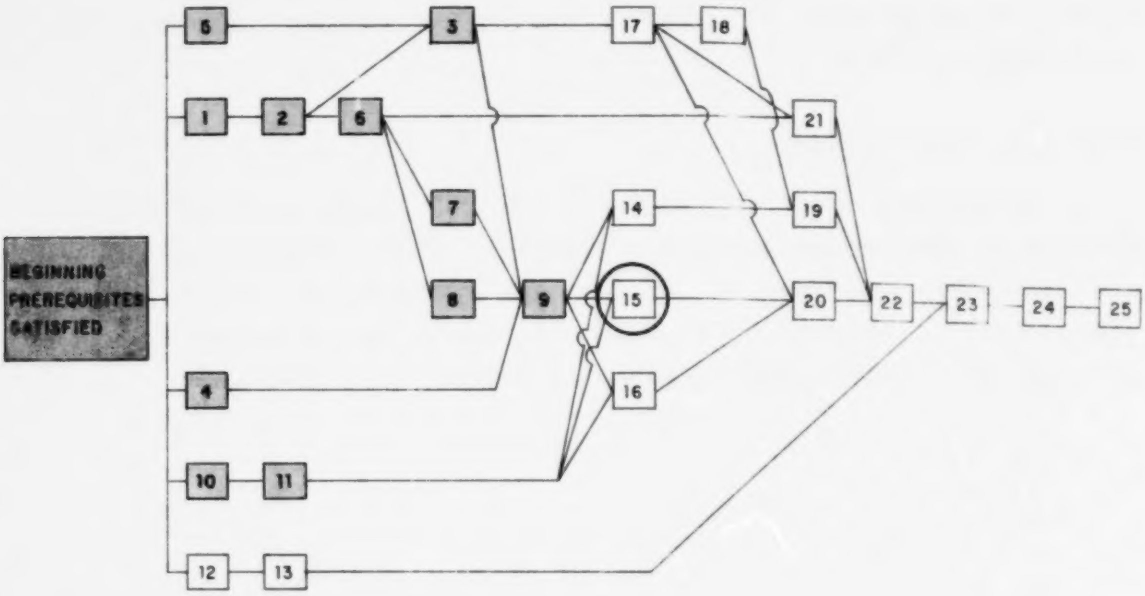
BEGINNING PREREQUISITES SATISFIED
5
3
17
18
1
2
6
21
7
14
19
8
9
15
20
22
23
24
25
4
16
10
11
12
13

Fig. 72. Prerequisites for Step 15

---

*This discussion applies specifically to CDMQC; if you are using another dispersion model, consult your users manual.

Table 19. Resource Requirements for Step 15

Necessary Skills[a]	Necessary Data	Data Sources	Necessary Hardware
Programming Data Analysis	Keypunched Data CDMQC Program	Step 9 Step 11	Computer with a Fortran G or H compiler

[a] First on list directs this step.

STEP 15A: VERIFY INPUT SEQUENCE

The input sequence for the cards in the calibration run was illustrated in Fig. 41 on pg. 95. The cards must be in this order or the program will not work.

STEP 15B: INSERT CONTROL LANGUAGE AND RUN PROGRAM

The control language for CDMQC will vary from computer to computer. Personnel trained in the operation of the computer you are using should be consulted. It may be possible that the control language from the test case of Step 11 can be used. The program should be run using an equivalent computer region of 250K.

STEP 15C: CHECK RESULTS

The printed output will be fairly long. It should be compared with the example CDMQC output provided in Appendix C of the CDMQC manual. If they are comparable, go to Step 16. If there are discrepancies, retrace earlier steps to see if the error can be found. Be sure to have a qualified programmer check the system completion codes and look for execution errors.

STEP 16: MAKE RIGHT-HAND-SIDE DISPERSION MODEL RUN*

SUMMARY

In Step 16 you make the right-hand-side (RHS) run of CDMQC. Three substeps are involved:

Step 16A: Verify Input Sequence
Step 16B: Insert Control Language and Run Program
Step 16C: Check Results

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

The RHS run cards must have been keypunched and checked for accuracy (Step 9). The CDMQC program acquired in Step 10 must have been tested as described in Step 11. The position of Step 16 in the EDZ methodology is shown in Fig. 73. The resources required are listed in Table 20.

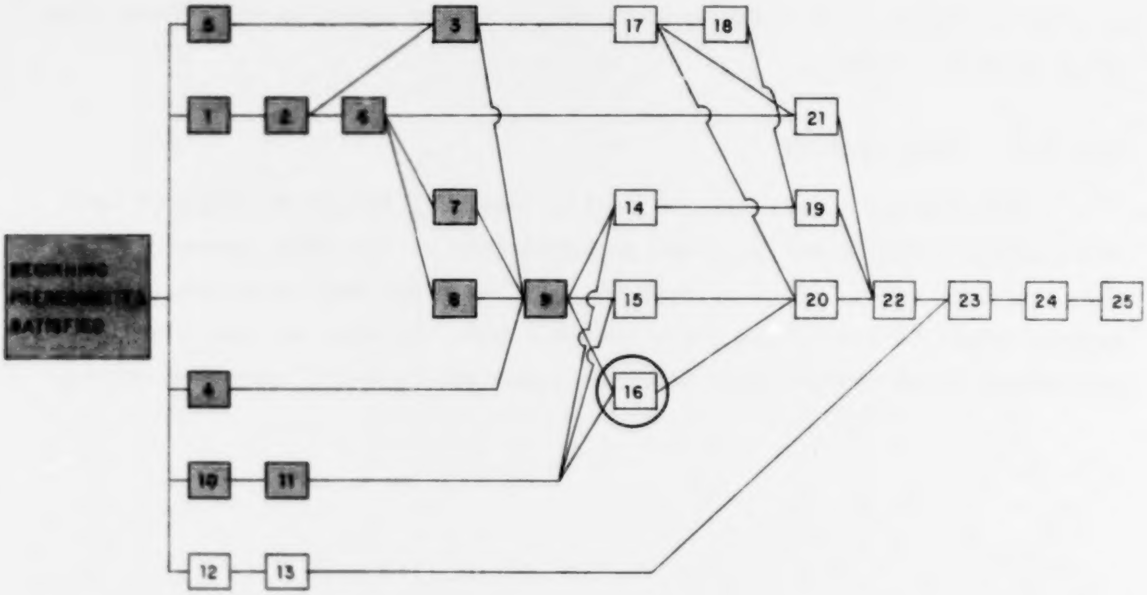
BEGINNING
PREREQUISITES
SATISFIED
5
1
2
6
3
7
8
9
4
10
11
12
13
17
18
21
14
19
15
20
22
23
24
25
16

Fig. 73. Prerequisites for Step 16

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*This discussion applies specifically to CDMQC; if you are using another dispersion model, consult your users manual.

Table 20. Resource Requirements for Step 16

Necessary Skills[a]	Necessary Data	Data Sources	Necessary Hardware
Programming Data Analysis	Keypunched Data CDMQC Program	Step 9 Step 11	Computer with a Fortran G or H compiler

[a] First on list directs this step.

STEP 16A: VERIFY INPUT SEQUENCE

The input sequence for the cards in the right-hand-side run was illustrated in Fig. 42 on pg. 96. The cards must be in this order or the program will not work.

STEP 16B: INSERT CONTROL LANGUAGE AND RUN PROGRAM

The control language for CDMQC will vary from computer to computer. Personnel trained in the operation of the computer you are using should be consulted. It may be possible that the control language from the test case of Step 11 can be used. The program should be run using an equivalent computer region of 250K.

STEP 16C: CHECK RESULTS

The printed output will be fairly long. It should be compared with the example CDMQC output provided in Appendix C of the CDMQC manual. If they are comparable, go on to Step 17. If there are discrepancies, retrace earlier steps to see if the error can be found. Be sure to have a qualified programmer check the system completion codes and look for execution errors.

STEP 17: SET UP LINEAR PROGRAM COEFFICIENT MATRIX

SUMMARY

The dispersion model runs are made to provide data for the linear program. In Step 17 you will set up a linear program coefficient matrix to be used in preparing the inputs to the linear program.

Although the matrix may be used for many formulations of EDZ,* the guidebook assumes you are following the "basic EDZ model." The basic EDZ model assumes that you would like to maximize the emissions produced in your region while not violating air quality standards. Maximizing emissions is assumed to be a proxy for maximizing economic growth, or at least maximizing flexibility in EDZ administration by knowing the maximum emissions allowed. Flexibility is introduced since you may decide on a lower level of emissions if you so desire. The basic EDZ model also assumes that area sources are exempt from EDZ.

Many data manipulations are required before the information can be coded and keypunched for use in linear programming. You will need several days (or weeks, depending on your staffing) to fill in the matrix by completing Steps 18-21.**

There are two substeps:

Step 17A: Draw Matrix

Step 17B: Fill in "Equation Type" Column

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

Steps 1, 2, 3, and 5 must be completed before Step 17 is begun, as shown in Fig. 74. Resource requirements are listed in Table 21.

---

*Several alternatives to the basic model are discussed in Benesh, et al. (1977).

**Many of the procedures in Steps 18 through 21 may be computerized. If you have the resources for the programming effort required, computerization may cut down on the time required to fill in the matrix.

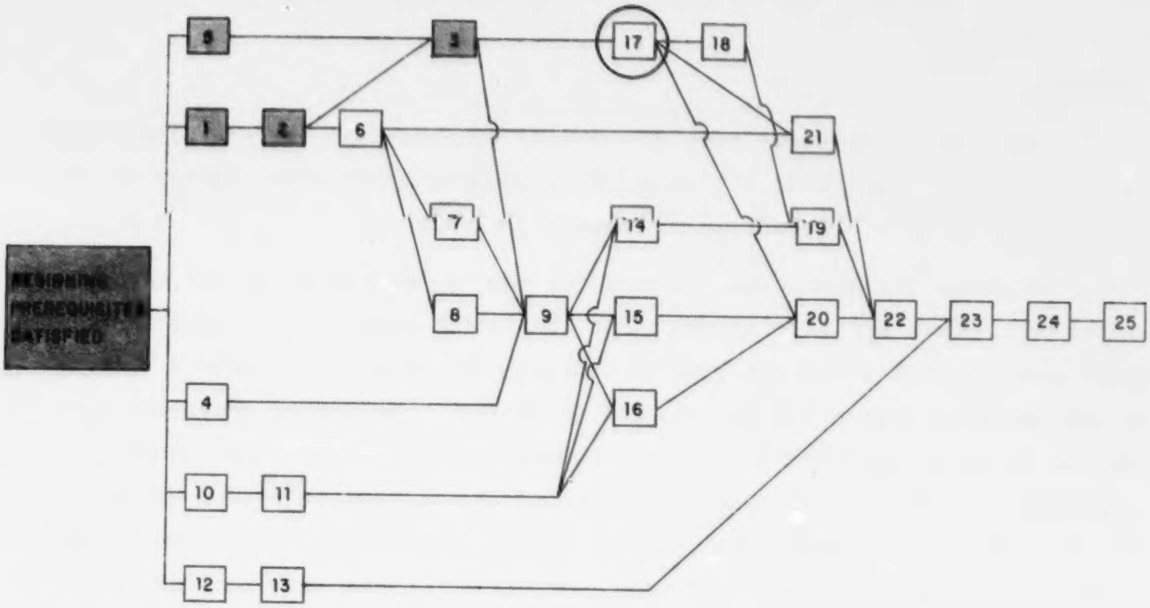


Fig. 74. Prerequisites for Step 17

STEP 17A: DRAW THE MATRIX

The format of the linear program coefficient matrix is shown in Fig. 75.* The matrix will be very large. The number of columns should equal four plus the number of EDZ sources identified in Worksheet 2. The number of rows should equal seven plus the number of receptors used in the RHS run of the dispersion model. Each cell in the matrix should be at least 1.6 cm wide and 1.3 cm high.

STEP 17B: FILL IN THE "EQUATION TYPE" COLUMN

The matrix shown in Fig. 75 shows the equation type column completed with an "N" in the objective function row and an "L" in ROW 001 to ROW XXX. Be sure each row has an "L" in the equation type column. The "L" indicates a less than or equal to ($\leq$) type of equation.

---

*This matrix is based on the assumption that you will use equal decay rates for SO_2 and particulates. If you use different decay rates, you must use a separate matrix for each pollutant. In this case, the matrix in Fig. 75 will change as follows: (1) each matrix will have only one RHS column, and (2) each matrix will have only one set of upper and lower bounds rows. The other dimensions will remain unchanged. The guidebook instructions are designed for use with the Fig. 75 matrix, but can easily be adapted to the two-matrix situation.

Table 21. Resource Requirements for Step 17

Necessary Skills	Necessary Data	Data Sources	Necessary Hardware
Data Analysis	No. of EDZ Receptors No. of EDZ Sources	Step 3 Worksheet 2	Very Large Piece of Paper

<table>
<tr><th>COLUMNS
ROWS</th><th>COL0001</th><th>COL0002</th><th>COL0003</th><th>COL0004</th><th>•••</th><th>COLYYYY</th><th>EQUATION TYPE</th><th>RHS FOR SO_2</th><th>RHS FOR PART</th></tr>
<tr><td>EXPLANATION OF COLUMNS</td><td></td><td></td><td></td><td></td><td></td><td></td><td>—</td><td>—</td><td>—</td></tr>
<tr><td>OBJECTIVE FUNCTION</td><td></td><td></td><td></td><td></td><td></td><td></td><td>N</td><td>—</td><td>—</td></tr>
<tr><td>ROW001</td><td></td><td></td><td></td><td></td><td></td><td></td><td>L</td><td></td><td></td></tr>
<tr><td>ROW002</td><td></td><td></td><td></td><td></td><td></td><td></td><td>L</td><td></td><td></td></tr>
<tr><td>ROW003</td><td></td><td></td><td></td><td></td><td></td><td></td><td>L</td><td></td><td></td></tr>
<tr><td>ROW004</td><td></td><td></td><td></td><td></td><td></td><td></td><td>L</td><td></td><td></td></tr>
<tr><td>ROW005</td><td></td><td></td><td></td><td></td><td></td><td></td><td>L</td><td></td><td></td></tr>
<tr><td>ROW006</td><td></td><td></td><td></td><td></td><td></td><td></td><td>L</td><td></td><td></td></tr>
<tr><td>•••</td><td></td><td></td><td></td><td></td><td></td><td></td><td>•••</td><td></td><td></td></tr>
<tr><td>ROWXXX</td><td></td><td></td><td></td><td></td><td></td><td></td><td>L</td><td></td><td></td></tr>
<tr><td>SO_2 UPPER BOUNDS</td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="3" rowspan="4">LINEAR PROGRAMMING COEFFICIENT MATRIX FOR SO_2 AND PARTICULATES</td></tr>
<tr><td>SO_2 LOWER BOUNDS</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>PART. UPPER BOUNDS</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>PART. LOWER BOUNDS</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Fig. 75. Linear Program Coefficient Matrix

STEP 18: ESTIMATE OBJECTIVE FUNCTION COEFFICIENTS

SUMMARY

In Step 18 you will calculate the objective function coefficients required for the linear program matrix. There are two substeps:

Step 18A: Fill in the "Explanation of Columns" Row

Step 18B: Fill in the "Objective Function" Row

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

Step 18 requires data from Step 2 and the matrix drawn in Step 17,* as shown in Fig. 76. Resource requirements are listed in Table 22.

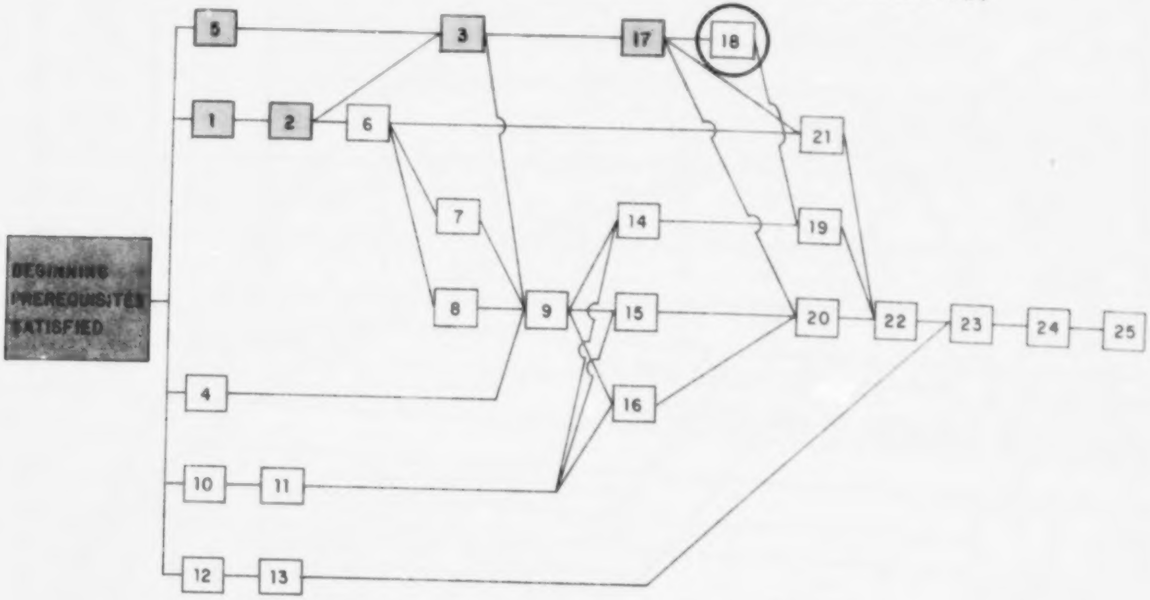


Fig. 76. Prerequisites for Step 18

Table 22. Resource Requirements for Step 18

Necessary Skills	Necessary Data	Data Source	Necessary Hardware
Data Analysis	EDZ Source Data	Step 2	Coefficient matrix from Step 17

---

*If you are using different decay rates for SO_2 and particulates, you will need two matrices; see Step 17.

STEP 18A: FILL IN THE "EXPLANATION OF COLUMNS" ROW

The "explanation of columns" row is included in the linear program coefficient matrix to help you read the linear program output and keep organized. This row shows which EDZ grid square and land use class are described by each column. The column numbers in the matrix are the same as the small numbers in the upper right corner of the "AREA" columns in Worksheet 2 (these are EDZ source numbers). It can be seen on Worksheet 2 that each upper right number identifies both an EDZ grid square and a land use class. Abbreviations for the square and class also are inserted into the "explanation of columns" row. See Fig. 77 for an illustration of how to fill in this matrix row.

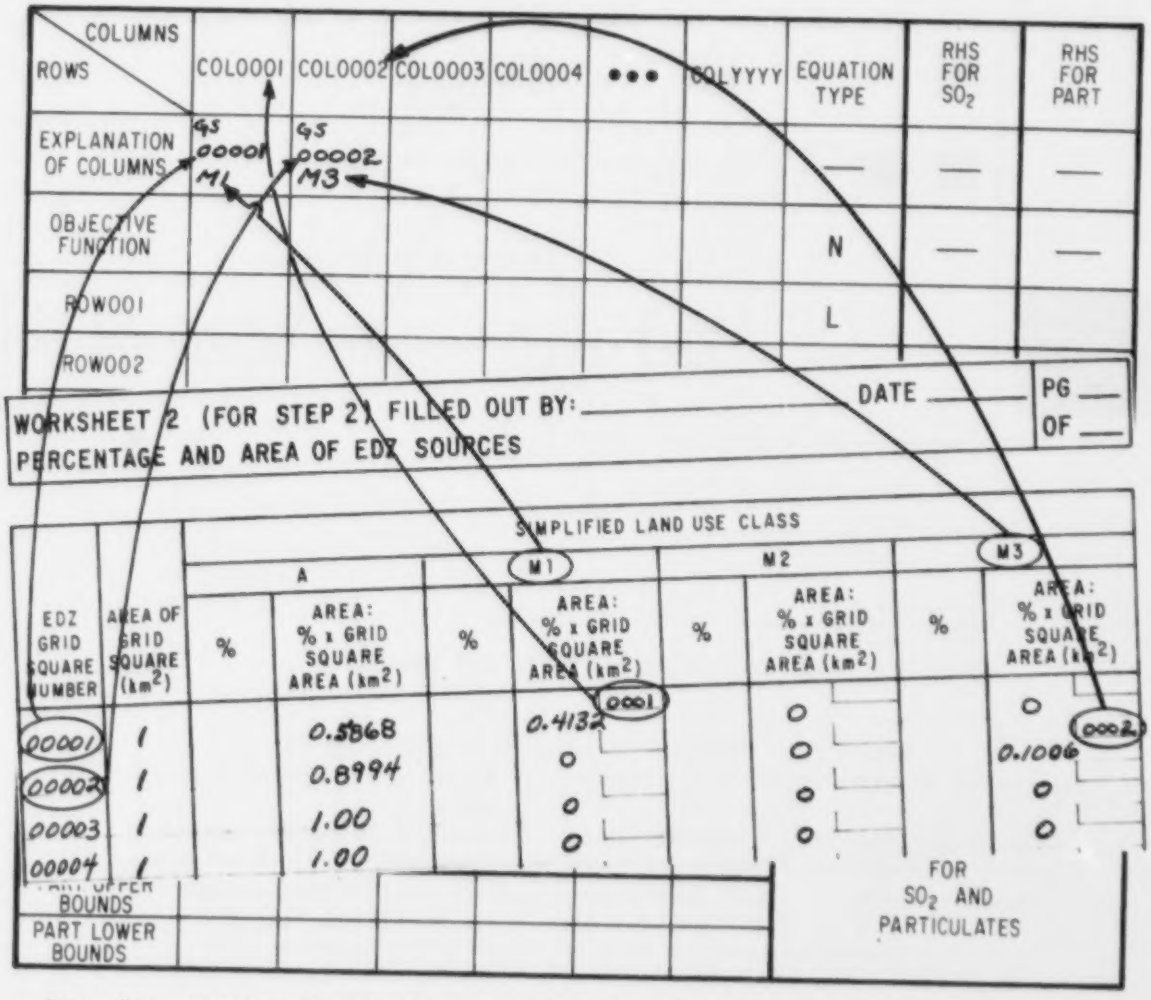
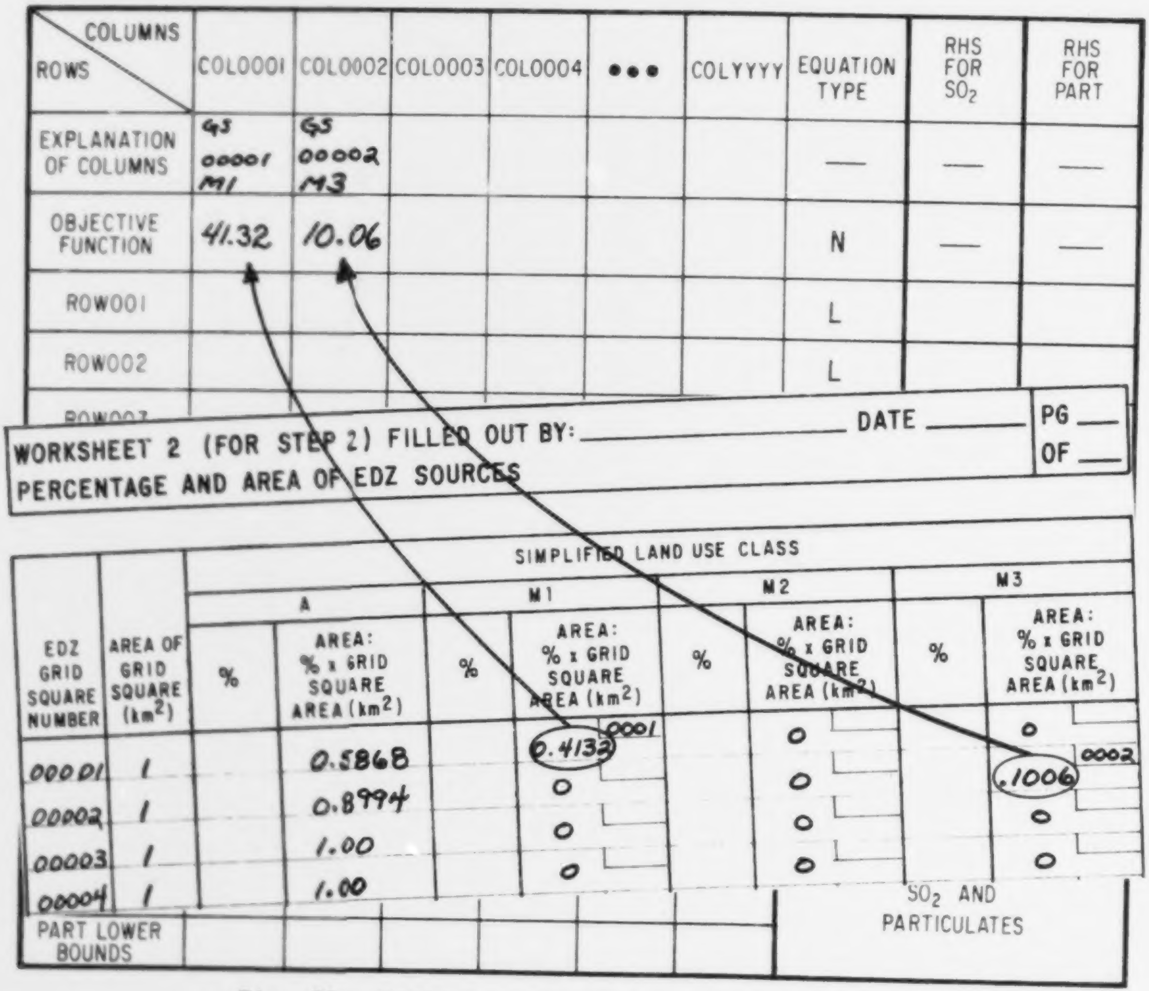

COLUMNS
ROWS
COL0001
COL0002
COL0003
COL0004
•••
COLYYYY
EQUATION TYPE
RHS FOR SO_2
RHS FOR PART
EXPLANATION OF COLUMNS
GS 00001 M1
GS 00002 M3
OBJECTIVE FUNCTION
N
ROW001
L
ROW002
WORKSHEET 2 (FOR STEP 2) FILLED OUT BY:
DATE
PG
OF
PERCENTAGE AND AREA OF EDZ SOURCES
SIMPLIFIED LAND USE CLASS
A
M1
M2
M3
EDZ GRID SQUARE NUMBER
AREA OF GRID SQUARE (km²)
%
AREA: % x GRID SQUARE AREA (km²)
0001
0002
00001
00002
00003
00004
1
0.5868
0.8994
1.00
0.4132
0
0.1006
PART UPPER BOUNDS
PART LOWER BOUNDS
FOR SO_2 AND PARTICULATES

Fig. 77. Filling in "Explanation of Columns" Row in Coefficient Matrix

STEP 18B: FILL IN THE "OBJECTIVE FUNCTION" ROW

The land areas in square kilometers for each land use class in each grid square (that is, for each EDZ source) are shown in Worksheet 2 in the "AREA" columns. Take the areas on Worksheet 2, which are in square kilometers, and multiply them by 100, to convert to hectares. Insert the hectare values in the appropriate squares in the "objective function" row, as shown in Fig. 78.



COLUMNS / ROWS	COL0001	COL0002	COL0003	COL0004	•••	COLYYYY	EQUATION TYPE	RHS FOR SO_2	RHS FOR PART
EXPLANATION OF COLUMNS	GS 00001 M1	GS 00002 M3					—	—	—
OBJECTIVE FUNCTION	41.32	10.06					N	—	—
ROW001							L		
ROW002							L		
ROW003									

WORKSHEET 2 (FOR STEP 2) FILLED OUT BY: ____________ DATE ________ PG ___
PERCENTAGE AND AREA OF EDZ SOURCES OF ___

EDZ GRID SQUARE NUMBER	AREA OF GRID SQUARE (km^2)	SIMPLIFIED LAND USE CLASS							
		A		M1		M2		M3	
		%	AREA: % x GRID SQUARE AREA (km^2)	%	AREA: % x GRID SQUARE AREA (km^2)	%	AREA: % x GRID SQUARE AREA (km^2)	%	AREA: % x GRID SQUARE AREA (km^2)
00001	1		0.5868		0.4132 0001		0		0
00002	1		0.8994		0		0		.1006 0002
00003	1		1.00		0		0		0
00004	1		1.00		0		0		0
PART LOWER BOUNDS									

SO_2 AND PARTICULATES

Fig. 78. Filling in the Objective Function Row

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STEP 19: ESTIMATE COLUMN AND ROW COEFFICIENTS

SUMMARY

In Step 19, you will calculate the "column and row" coefficients for the linear program matrix.

PREVIOUS STEPS AND RESOURCE REQUIREMENTS

Step 19 requires data from the dispersion model air quality runs (Step 14), the matrix drawn in Step 17,* and Step 18's objective function coefficients. The position of Step 19 in the EDZ methodology is shown in Fig. 79. Resource requirements are listed in Table 23.

CALCULATE "COLUMN AND ROW" COEFFICIENTS

The "column and row" section of the matrix is shown in Fig. 80. Each space in the column and row section will be filled with a value derived by multiplying the objective function coefficient in each column by a "transfer coefficient."

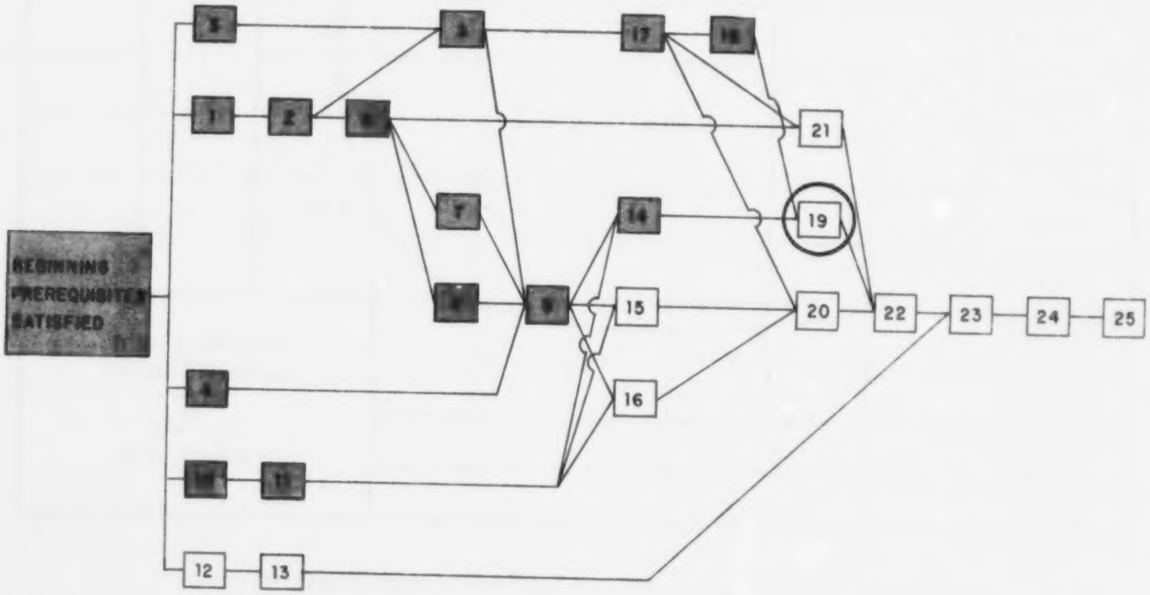

Fig. 79. Prerequisites for Step 19

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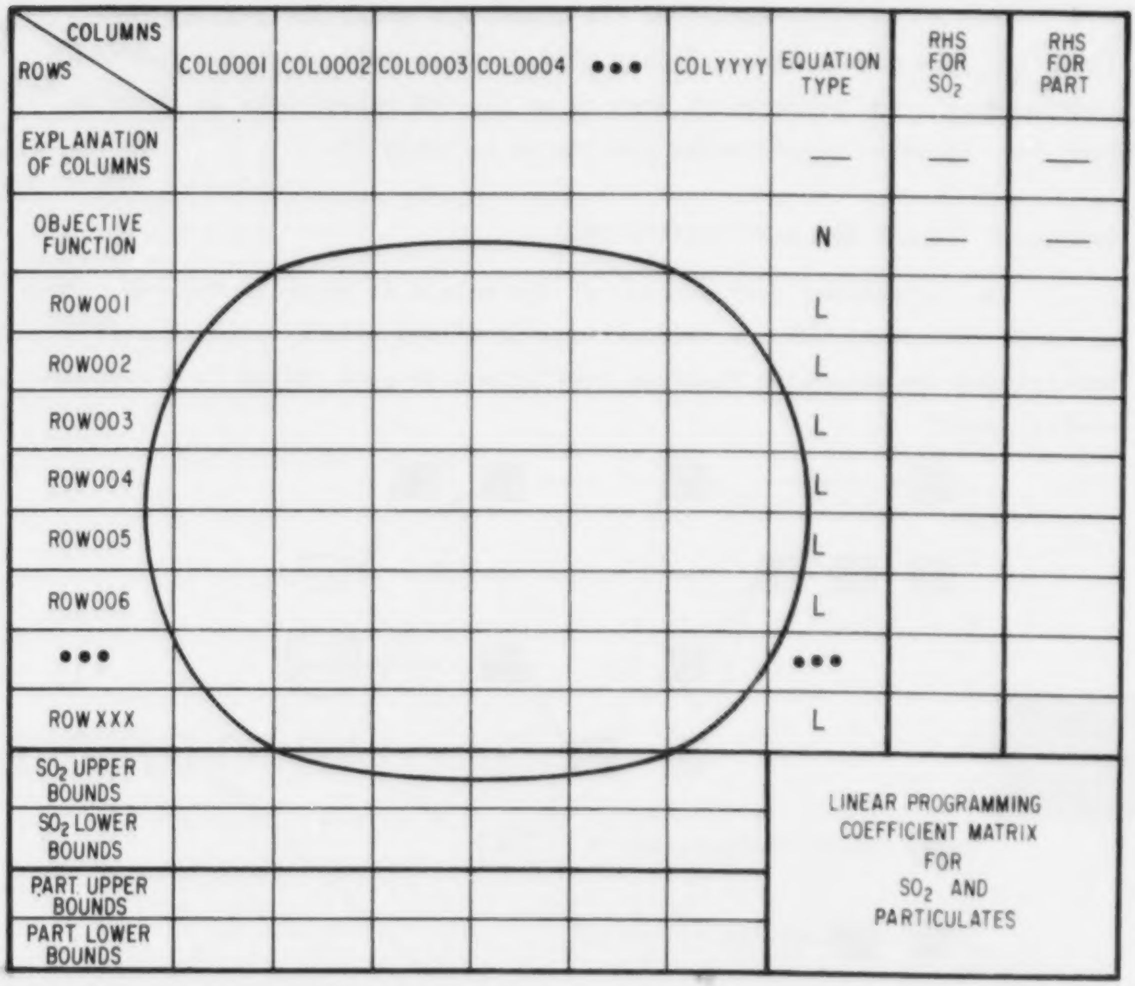
*If you are using different decay rates for SO_2 and particulates, you will need two matrices (see Step 17).

Table 23. Resource Requirements for Step 19

Necessary Skills	Necessary Data	Data Source	Necessary Hardware
Data Analysis	Disperson Model Air Quality Run Objective Function	 Step 14 Step 18	Coefficient Matrix (Step 17)



ROWS \ COLUMNS	COL0001	COL0002	COL0003	COL0004	•••	COLYYYY	EQUATION TYPE	RHS FOR SO_2	RHS FOR PART
EXPLANATION OF COLUMNS							—	—	—
OBJECTIVE FUNCTION							N	—	—
ROW001							L		
ROW002							L		
ROW003							L		
ROW004							L		
ROW005							L		
ROW006							L		
•••							•••		
ROWXXX							L		
SO_2 UPPER BOUNDS							LINEAR PROGRAMMING COEFFICIENT MATRIX FOR SO_2 AND PARTICULATES		
SO_2 LOWER BOUNDS									
PART UPPER BOUNDS									
PART LOWER BOUNDS									

Fig. 80. "Column and Row" Section of Coefficient Matrix

Secure the output of the three CDMQC air quality runs and find the pages that list "Individual Source Contributions" for a certain receptor; under this heading find the columns for "Area Sources" (see Fig. 81).* The "1A, 2A, 3A,..." designations identify the order in which the area source cards were put into the computer. Grid square numbers should be written next to these designations (see Fig. 82). Each grid square would be contributing the amount of pollutant listed in the "micrograms/cu. meter" column to the receptor if the light, medium, or heavy manufacturing sources in the square were emitting 10,000 g/s of the pollutant.

To fill in the columns and rows section:

1. For each receptor/source pair, multiply an entry in the "micrograms/cu. meter" by the appropriate objective function coefficient. See Fig. 82.
2. Divide the above result by 10,000, and record the result in the appropriate square in the matrix. See Fig. 82.**

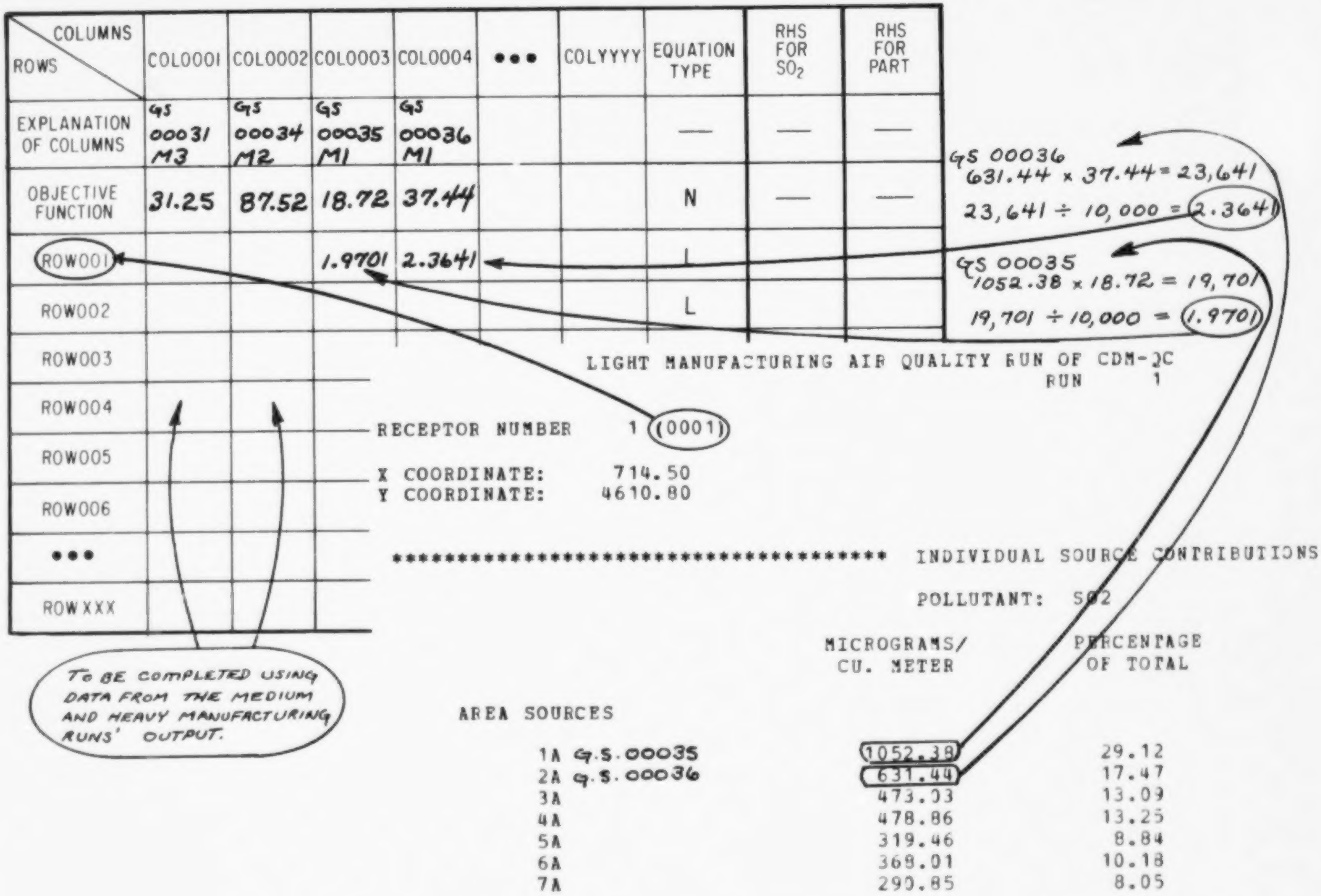
---

*The same type of information can be obtained from the sections of the AQDM output labeled "Source Contributions for Five Selected Receptors"; see Appendix G, Sec. 1, and the AQDM users manual.

**The actual "transfer coefficients" are the entries in the "micrograms/cu-meter" column divided by 10,000. Conceptually, the transfer coefficients are multiplied by the objective function coefficients to obtain entries for the columns and rows section. However, in practice it is simpler to follow the two-step procedure given above in the text; the two methods of calculation will, of course, give the same numerical result.

```
                    C L I M A T O L O G I C A L   D I S P E R S I O N   M O D E L

           LIGHT MANUFACTURING AIR QUALITY RUN OF CDM-QC FOR THE CLEANAIR CITY EXAMPLE
                                             RUN      1

RECEPTOR NUMBER     1 (0001)

X COORDINATE:      714.50
Y COORDINATE:     4610.80

******************************************  INDIVIDUAL SOURCE CONTRIBUTIONS  ******************************

                                            POLLUTANT:  SO2                     POLLUTANT: PART

                                     MICROGRAMS/        PERCENTAGE          MICROGRAMS/        PERCENTAGE
                                      CU. METER          OF TOTAL            CU. METER          OF TOTAL

      AREA SOURCES

            1A                        1052.38             29.12              1052.38             29.12
            2A                         631.44             17.47               631.44             17.47
            3A                         473.03             13.09               473.03             13.09
            4A                         478.86             13.25               478.86             13.25
            5A                         319.46              8.84               319.46              8.84
            6A                         368.01             10.18               368.01             10.18
            7A                         290.85              8.05               290.85              8.05

      SOURCES INDIVIDUALLY CON-
      TRIBUTING LESS THAN  0.0 %         0.0               0.0                 0.0               0.0

      BACKGROUND                         0.0               0.0                 0.0               0.0

      TOTAL                           3614.11            100.00              3614.11            100.00
```

Fig. 81. Sample CDMQC Output for Area Source Contributions



ROWS \ COLUMNS	COL0001	COL0002	COL0003	COL0004	•••	COLYYYY	EQUATION TYPE	RHS FOR SO_2	RHS FOR PART
EXPLANATION OF COLUMNS	GS 00031 M3	GS 00034 M2	GS 00035 M1	GS 00036 M1			—	—	—
OBJECTIVE FUNCTION	31.25	87.52	18.72	37.44			N	—	—
ROW001			1.9701	2.3641			L		
ROW002							L		
ROW003									
ROW004									
ROW005									
ROW006									
•••									
ROWXXX									

GS 00036
631.44 × 37.44 = 23,641
23,641 ÷ 10,000 = 2.3641

GS 00035
1052.38 × 18.72 = 19,701
19,701 ÷ 10,000 = 1.9701

TO BE COMPLETED USING DATA FROM THE MEDIUM AND HEAVY MANUFACTURING RUNS' OUTPUT.

```
                    LIGHT MANUFACTURING AIB QUALITY BUN OF CDM-2C
                                                        RUN      1

RECEPTOR NUMBER     1 (0001)

X COORDINATE:      714.50
Y COORDINATE:     4610.80

****************************************  INDIVIDUAL SOURCE CONTRIBUTIONS

                                          POLLUTANT:  SO2

                                    MICROGRAMS/       PERCENTAGE
                                     CU. METER         OF TOTAL

       AREA SOURCES

            1A G.S.00035             1052.38            29.12
            2A G.S.00036              631.44            17.47
            3A                        473.03            13.09
            4A                        478.86            13.25
            5A                        319.46             8.84
            6A                        368.01            10.18
            7A                        290.85             8.05
```

Fig. 82. Filling in the "Column and Row" Section of Coefficient Matrix

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STEP 20: ESTIMATE RIGHT-HAND-SIDE (RHS) COEFFICIENTS

SUMMARY

In Step 20 you will calculate the right-hand-side (RHS) coefficients for the linear program matrix. The three substeps are:

Step 20A: Convert Geometric Means to Arithmetic Means

Step 20B: Calibrate Standards and Calculate RHS Coefficients

Step 20C: How to Deal with Negative RHS Coefficients

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

To complete Step 20, you need to know the air quality standard(s) being applied in your region. These may be the NAAQS, state or local standards, standards related to PSD, or others. Check with your state air pollution control agency and EPA regional office as to which standards apply. You will need the output from the dispersion model calibration and RHS runs and the coefficient matrix drawn in Step 17.* Figure 83 illustrates the position of Step 20 in the EDZ methodology. Resource requirements are listed in Table 24.

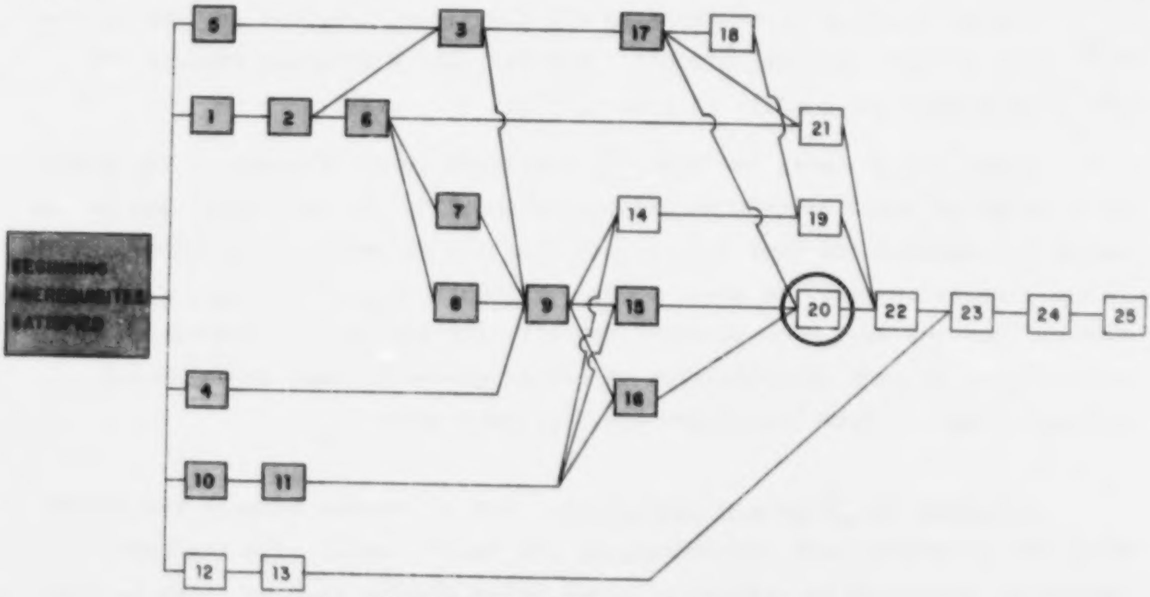

Fig. 83. Prerequisites for Step 20

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*If you are using different decay rates for SO_2 and particulates, you will need two matrices (see Step 17).

Table 24. Resource Requirements for Step 20

Necessary Skills	Necessary Data	Data Sources	Necessary Hardware
Data Analysis	Air Quality Standards	Step 1	Coefficient Matrix (Step 17)
	Dispersion Model Calibration Run	Step 15	
	Dispersion Model RHS Run	Step 16	
	Air Quality Projections	See text	

STEP 20A: CONVERT GEOMETRIC MEANS TO ARITHMETIC MEANS

You may have noticed a discrepancy between the CDMQC output for particulate concentrations and the annual particulate standard of the NAAQS: CDMQC provides arithmetic means while the NAAQS are stated in geometric means.* In order to compare these two types of average concentrations, the output and standards must be placed on common ground.

An arithmetic mean for a set of "n" values is found by summing the values and dividing the result by "n." An arithmetic mean is what is commonly refered to as an "average." In contrast, a geometric mean for a set of "n" values is found by multiplying all the values together and taking the "n^{th}" root of the resulting product. However, the difference between the two in measuring air quality is generally not very great.

There are at least two ways for resolving this difference. The first is an accepted practice used in dispersion modeling; it is simple, and is the method recommended for your use: assume that the geometric mean calculated by the dispersion model is equal to the arithmetic mean. The second, a more complex "map and switch" procedure, converts the air quality standard for particulates at each receptor from an annual geometric mean to an annual arithmetic mean. Both approaches are discussed below.

Assuming the Means are Equivalent. The difference between the arithmetic and geometric mean concentrations are fairly small, with the concentration predicted by arithmetic means being greater than or equal to that estimated using the geometric mean. If you simply assume that the arithmetic mean equals the geometric mean, your calculations will be in error toward having better air quality than required by the NAAQS. This error will tend to make the EDLs more restrictive than necessary and thus make the cost of compliance higher. However, the difference should not be very large.

---

*If you are using AQDM you will also have this problem.

Using the "Map and Switch" Procedure. To convert the particulate standards applicable at each receptor to annual arithmetic means, you will need to know:

- the locations of the EDZ receptor points (mapped in Step 3),
- the locations of the monitoring stations (these are recorded on Worksheet 5 and should already have been mapped onto the same map as the receptors; if they are not, do it now),
- the 24-hour standard geometric deviations for each monitoring station (recorded on Worksheet 5), and
- the air quality standard for particulates applicable at each EDZ receptor and monitoring station location (mapped in Step 2)

You will also need a scientific calculator and some mapping skills. The procedure is as follows:*

First, list the air quality standard ($\mu g/m^3$ annual geometric mean) applicable for each receptor in Column A of Worksheet 12 (see Fig. 84).** Second transfer the 24-hour geometric standard deviations for each monitoring station listed on Worksheet 5 to your map of regional monitoring stations, and draw an isopleth map of the standard geometric deviations, using straight-line interpolation between monitoring stations where needed (see Fig. 85).†

Third, using the isopleth map, estimate the standard geometric deviations at each EDZ receptor point and record them in Column B on Worksheet 12. Fourth, perform the calculations indicated in the remaining columns on Worksheet 12.†† If these calculations are performed on a calculator or via the formula listed in the right-hand column of Worksheet 12, the intermediate columns need not be filled in.

---

*For more information on the mechanics of this method consult Larsen (1971).

**Full page blank worksheets for your use are provided in Appendix J.

†See Robinson & Sale, 1969, pp. 151-164; and Harvard University, 1968.

††Refer to the CDMQC manual if you have questions about this procedure.

WORKSHEET 12 (FOR STEP 20) FILLED OUT BY: ______________ DATE ______ CONVERTING GEOMETRIC MEANS TO ARITHMETIC MEANS FOR PARTICULATES	PG 3 OF 10

RECEPTOR NUMBER	A AIR QUALITY STD APPLICABLE AT RECEPTOR, ANNUAL GEOMETRIC MEAN, IN $\mu g/m^3$ (Mg)	B STD GEOMETRIC DEVIATION (24HR) AT RECEPTOR, IN $\mu g/m^3$ (Sg)	SQUAREROOT OF Sg $(\sqrt{Sg})$	C NATURAL LOGARITHMS OF SQUAREROOT OF Sg $(\ln\sqrt{Sg})$	D COLUMN B RAISED TO THE COLUMN C POWER $(Sg^{\ln\sqrt{Sg}})$	ANNUAL ARITHMETIC MEAN, IN $\mu g/m^3$ (COL. A X COL. D) $\chi = Mg\, Sg^{\ln\sqrt{Sg}}$
0054	60	1.37	1.17	0.157	1.05	63.0
0055	60	1.55	1.24	0.215	1.10	66.0
0056	50	1.58	1.26	0.231	1.11	55.5
0057	50	1.48	1.22	0.199	1.08	54.0

Fig. 84. Worksheet 12 Example

STEP 20B: CALIBRATE STANDARDS AND CALCULATE RHS COEFFICIENTS

The annual arithmetic mean standards for SO_2 and particulates must be adjusted by using the calibration coefficients provided by the CDMQC calibration run. In the output of that run, there are two sections titled "Calibration Procedure Results: SO_2" and "Calibration Procedure Results: Part." Under each of these sections is a set of three parameters labeled "Slope," "Intercept," and "Background." The background value will be zero and is to be ignored since for the EDZ methodology it is included in the intercept value. The slope and intercept are to be inserted into the equation below and the X value calculated repeatedly for both pollutants at all the receptors.* Place the answer obtained for the X's in Column A of Worksheet 13 (shown in Fig. 86). This equation is sometimes called the "reverse calibration" equation.

$$X = \frac{y - a}{b}$$

where:

X = calibrated standard at each receptor in $\mu g/m^3$ (enter in Column A of Worksheet 13);

---

*If your region has more than 200 point sources, you will have calculated the slope and intercept using the method presented in Appendix I.

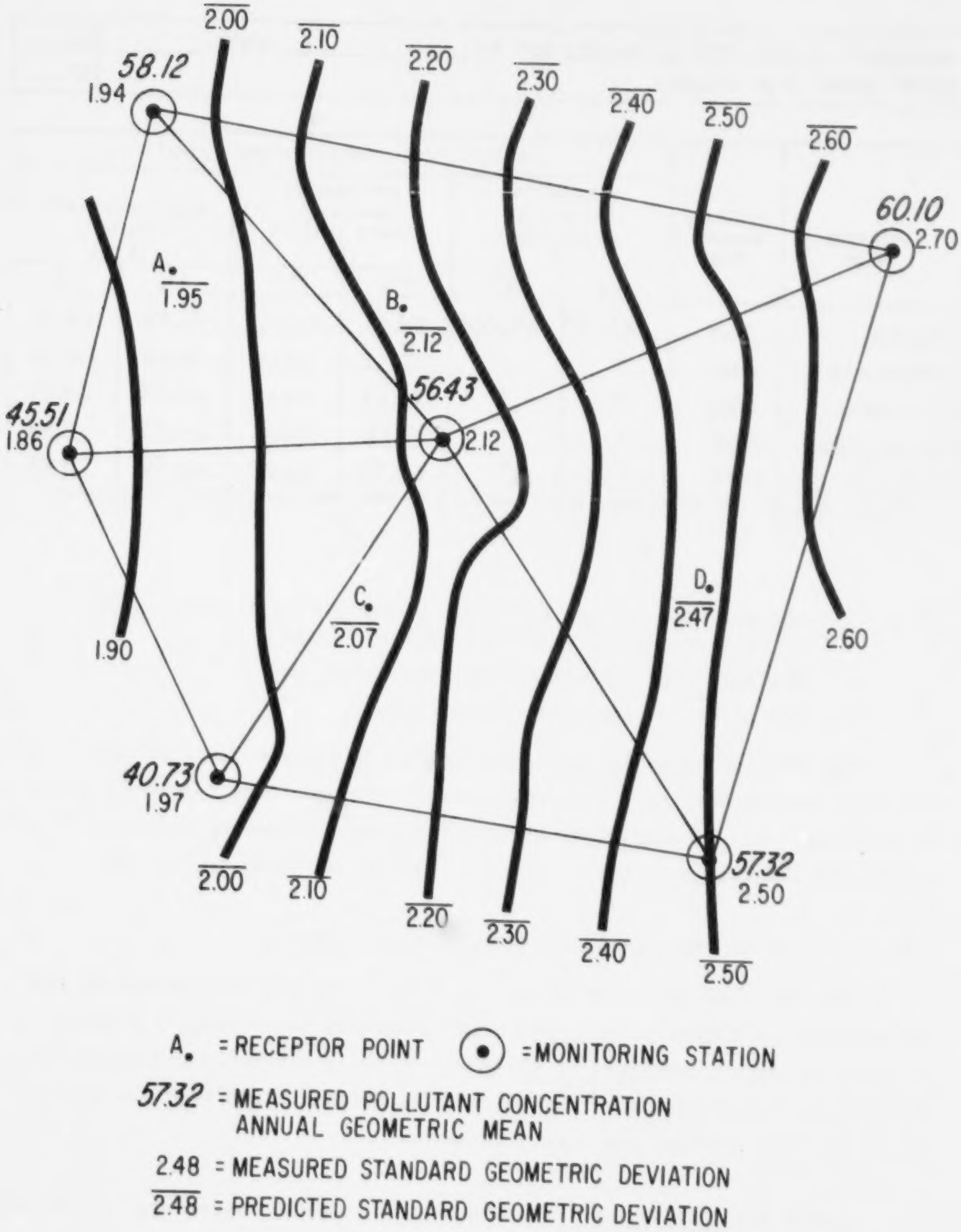

$\overline{2.00}$
$\overline{2.10}$
$\overline{2.20}$
$\overline{2.30}$
$\overline{2.40}$
$\overline{2.50}$
$\overline{2.60}$
58.12
1.94
60.10
2.70
A.
$\overline{1.95}$
B.
$\overline{2.12}$
45.51
1.86
56.43
2.12
C.
$\overline{2.07}$
D.
$\overline{2.47}$
1.90
2.60
40.73
1.97
57.32
2.50
$\overline{2.00}$
$\overline{2.10}$
$\overline{2.20}$
$\overline{2.30}$
$\overline{2.40}$
$\overline{2.50}$
A. = RECEPTOR POINT
⊙ = MONITORING STATION
57.32 = MEASURED POLLUTANT CONCENTRATION ANNUAL GEOMETRIC MEAN
2.48 = MEASURED STANDARD GEOMETRIC DEVIATION
$\overline{2.48}$ = PREDICTED STANDARD GEOMETRIC DEVIATION

Fig. 85. Isopleth Map of Standard Geometric Deviation

WORKSHEET 13 (FOR STEP 20) FILLED OUT BY: ______________ RIGHT-HAND-SIDE VALUES	DATE: ________	PG ___ OF ___

RECEPTOR NAME	RECEPTOR NUMBER (ROW)	AIR POLLUTANT CONCENTRATIONS ($\mu g/m^3$)					
		CALIBRATED AIR QUALITY STANDARD (A)		AIR QUALITY IMPACT OF EXEMPT SOURCES (B)		RIGHT-HAND-SIDE VALUE (A-B)	
		SO_2	PART	SO_2	PART	SO_2	PART
ROHAN	0001	123.71*	69.00*	44.26	44.26	79.45	24.74
STATE UNIV,	0002	"	"	53.63	53.63	70.08	15.37
BOMBADIL	0003	"	"	34.62	34.62	89.09	34.39
TB HOSPITAL	0004	"	"	59.12	59.12	64.59	9.88
CLEANAIR	0005	"	"	60.75	60.57	62.96	8.25

*THESE FIGURES ARE TAKEN FROM THE CLEANAIR CITY TEST CASE, COMPUTATIONS ARE IN APPENDIX

Fig. 86. Worksheet 13 Example

y = the standard for one pollutant at one receptor point calculated as an annual arithmetic mean, in $\mu g/m^3$;

a = the intercept for the calibration curve; and

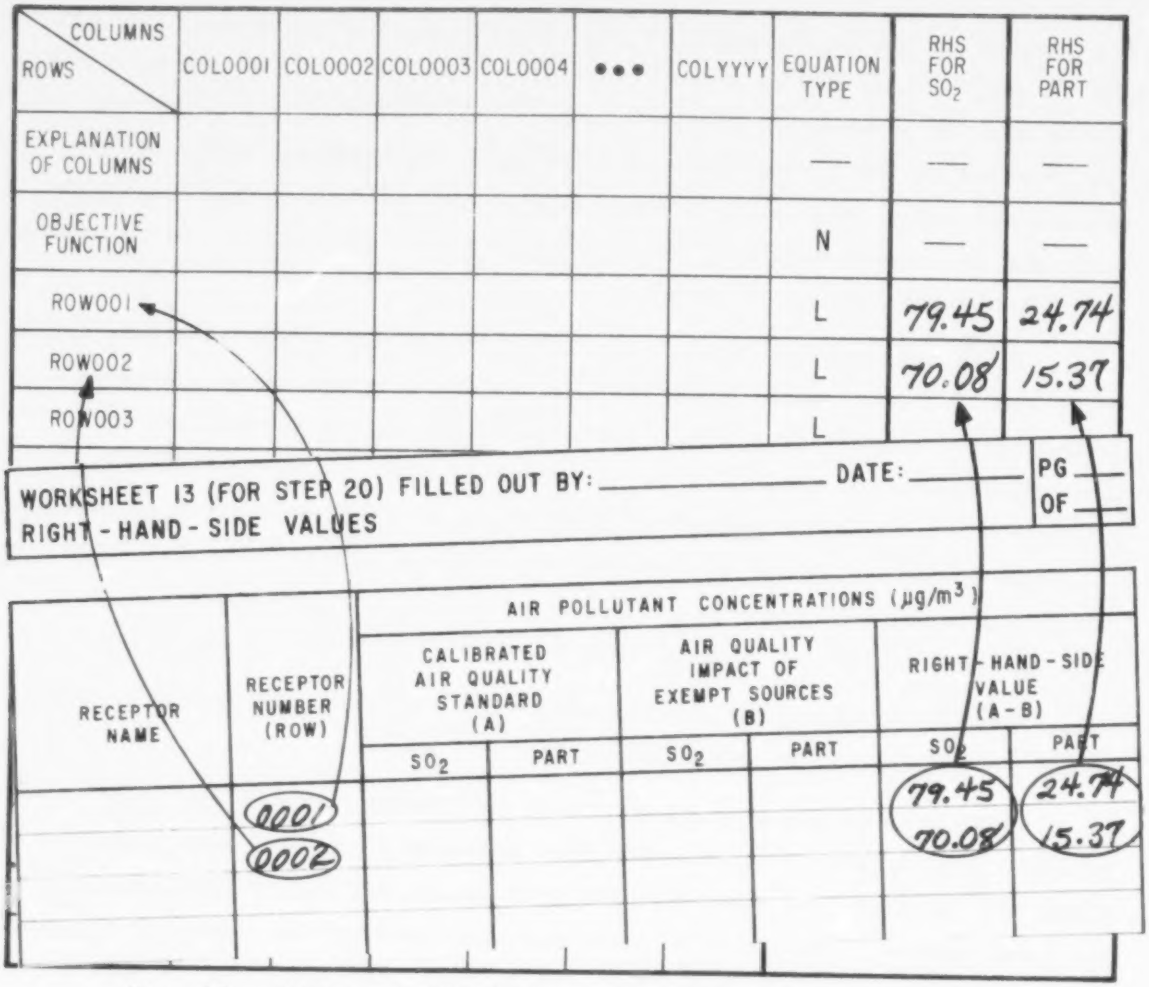
b = the slope for the calibration curve.

The RHS run (Step 16) predicted pollution contributions at each receptor from sources not subject to EDZ control. Record these values in Column B of Worksheet 13. Finally, complete the final two columns on Worksheet 13, and record the values in the coefficient matrix, as shown in Fig. 87.

STEP 20C: HOW TO DEAL WITH NEGATIVE RHS COEFFICIENTS

You may find that some receptors (rows) have negative values in the RHS columns. A negative RHS coefficient indicates that either (1) there is an error in the calculations or (2) your region is currently violating, or in the near future will violate, air quality standards and needs an air pollution control strategy aimed at attainment.

Check RHS Calculations. Return to the data that were used to generate the RHS values and check to see that they were copied correctly from their sources. Next, check the calculations in Worksheet 13. If you find no errors, your region either has or soon will have an attainment problem.



COLUMNS / ROWS	COL0001	COL0002	COL0003	COL0004	•••	COLYYYY	EQUATION TYPE	RHS FOR SO_2	RHS FOR PART
EXPLANATION OF COLUMNS							—	—	—
OBJECTIVE FUNCTION							N	—	—
ROW001							L	79.45	24.74
ROW002							L	70.08	15.37
ROW003							L		

WORKSHEET 13 (FOR STEP 20) FILLED OUT BY: ______________ DATE: ________ PG ___ OF ___

RIGHT-HAND-SIDE VALUES

RECEPTOR NAME	RECEPTOR NUMBER (ROW)	AIR POLLUTANT CONCENTRATIONS ($\mu g/m^3$)					
		CALIBRATED AIR QUALITY STANDARD (A)		AIR QUALITY IMPACT OF EXEMPT SOURCES (B)		RIGHT-HAND-SIDE VALUE (A-B)	
		SO_2	PART	SO_2	PART	SO_2	PART
	0001					79.45	24.74
	0002					70.08	15.37

Fig. 87. Filling in RHS Columns of Coefficient Matrix

Attainment Problems. Since State Implementation Plans (SIPs) are required to contain provisions for meeting air quality standards, you should consult your state pollution control authority if you have current or future attainment problems. If the SIP includes a strategy for attainment, it should include projected pollutant concentrations in the region. These projections should be substituted for those used to calculate the RHS coefficients. If the projections are accurate, all the RHS coefficients should then be positive.

EDZ can be one part of a strategy aimed at attaining and maintaining air quality standards. In fact, even if EDZ itself is not implemented, the EDZ analysis can be used in forming other attainment strategies. For example, a variation of EPA's offset policy may be implemented through your EDZ work. The EDZ methodology can be used to determine where and to what degree offsets can be applied in order to attain standards. In addition, the magnitudes of the required emission reductions would be based on objective criteria; specifically, the meteorology of your region and the current land use plans. Following is an explanation of one way that the EDZ guidebook could be altered to apply the methodology to offsets.

First, all exemptions for area and point sources would be eliminated. Thus, each RHS value would equal the air quality standard minus the background concentrations as defined by the intercept of the calibration equation, divided by the slope of the calibration curve. If any of these new RHS values are negative, the solution requires an attainment strategy beyond the scope of the guidebook because the new negative RHS implies that background concentrations are higher than permitted by the standards. In this situation, the state and federal EPAs should be contacted for assistance.

Second, assuming the new RHS values are positive, the linear program should be run exactly as described in Steps 22 and 23.

Third, an emission quota should be calculated for each EDZ grid square. This is done by taking the EDLs calculated by the linear program (Step 23) for each land use class and grid square and multiplying these by the total number of hectares in each land use class in the same grid square (Worksheet 2 provides the total hectares in each land use class in each grid square). When these multiplications are finished, they are summed for each grid square to produce the emission quota for each EDZ grid square. Figure 88 helps explain this procedure.

Fourth, using data from the emission inventory (Step 6) and the gridded simplified zoning maps (Step 2), determine which point and area sources are located in each EDZ grid square. Area source emissions should be allocated from emission inventory grid squares to EDZ grid squares in a statistically acceptable manner.

Fifth, using an approved method, such as that found in the *EPA Guidelines for Air Quality Maintenance Planning and Analysis*, Vols. 7 and 10, or a method obtained from the state or local air pollution control authority,

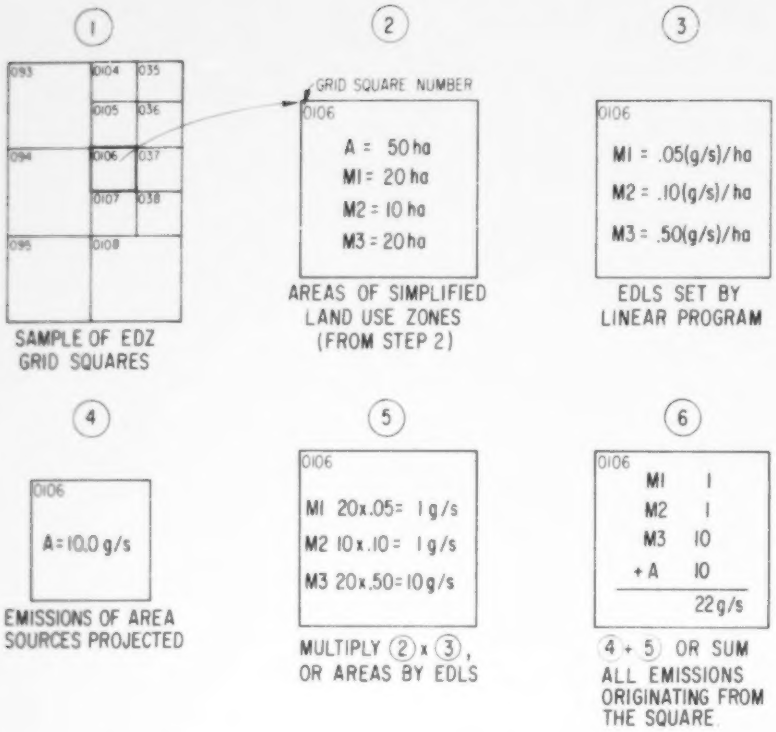

①
093
0104
035
0105
036
094
0106
037
0107
038
095
0108
SAMPLE OF EDZ GRID SQUARES
②
GRID SQUARE NUMBER
0106
A = 50 ha
MI = 20 ha
M2 = 10 ha
M3 = 20 ha
AREAS OF SIMPLIFIED LAND USE ZONES (FROM STEP 2)
③
0106
MI = .05(g/s)/ha
M2 = .10(g/s)/ha
M3 = .50(g/s)/ha
EDLS SET BY LINEAR PROGRAM
④
0106
A=10.0 g/s
EMISSIONS OF AREA SOURCES PROJECTED
⑤
0106
MI 20x.05= 1 g/s
M2 10x.10= 1 g/s
M3 20x.50=10 g/s
MULTIPLY ② x ③, OR AREAS BY EDLS
⑥
0106
MI 1
M2 1
M3 10
+A 10
22 g/s
④ + ⑤ OR SUM ALL EMISSIONS ORIGINATING FROM THE SQUARE

Fig. 88. Calculating Emission Quotas

estimate the emissions for existing sources (in g/s) as if they were in compliance with all existing emission control regulations.

Sixth, for each EDZ grid square, sum the projected emissions from each of the sources within its borders. This calculation will give the total projected emissions for each EDZ grid square. Then for each EDZ grid square, subtract the total projected emissions from the emission quota. The resulting values, one for each grid square, will be called increments. The positive increments are for grid squares whose total emissions could increase by the incremental value without further violating standards if the squares with negative increments decreased their total emissions by their increments.

Assuming that no increase in emissions will be allowed in negative increment squares, the potential for tradeoffs is clear. When a new source locates, or an old source expands, in a positive increment square, the source should be encouraged to negotiate offsets with the pollution control authority and the sources in negative increment squares.

Once the air quality standard is reached, the EDZ strategy used to attain standards can then be used to maintain the standards.

STEP 21: ESTIMATE UPPER AND LOWER BOUND COEFFICIENTS

SUMMARY

In Step 21 you will estimate the upper and lower bound coefficients for the linear program matrix.

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

Step 21 requires data from the emission inventory (Step 6) and the matrix drawn in Step 17; see Fig. 89. Worksheet 8 (Step 6) must have been completed. Personnel and data requirements are listed in Table 25.

SETTING UPPER AND LOWER BOUNDS

The Need for Bounds

Setting upper and lower bounds ensures that the resulting EDLs are technically and politically reasonable. The upper bound represents the maximum emission density for sources in a particular land use class. By setting the upper bound, you avoid the chance that the linear programming

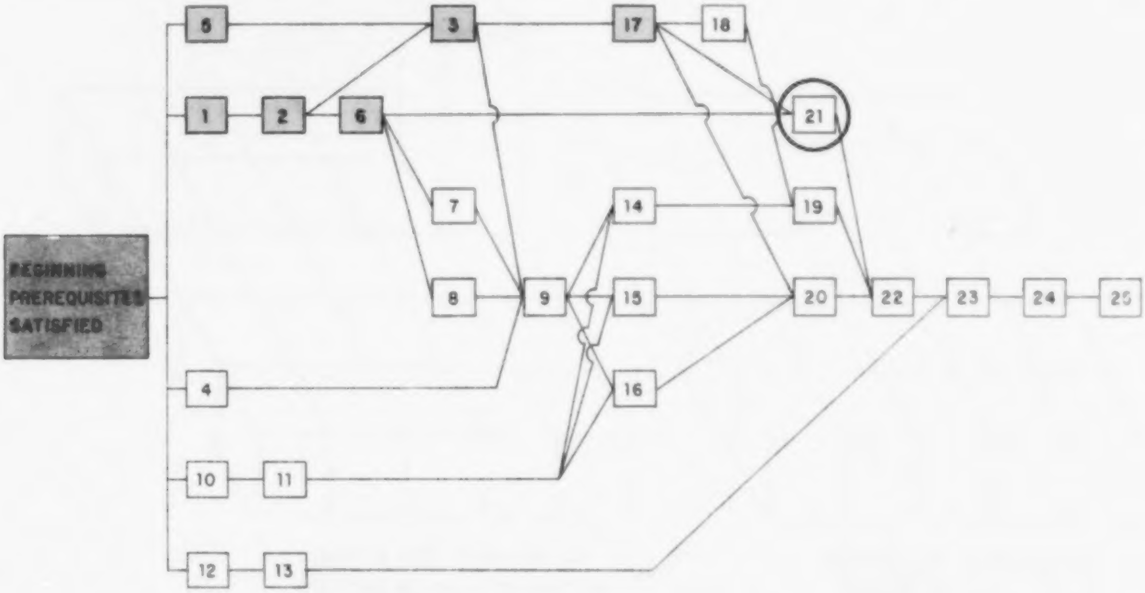


Fig. 89. Prerequisites for Step 21

Table 25. Resource Requirements for Step 21

Necessary Skills[a]	Necessary Data	Data Sources	Necessary Hardware
Land Use Planning Data Analysis Possibly Air Pollution Control Expertise	Zoning Maps and Ordinances Worksheet 8 Emission Inventory	Step 2 Step 6 Step 6	None

[a] First on list directs this step.

package will place an absurdly high EDL anywhere in the region. Figure 90 graphically shows the possible consequences of not having an upper bound.

Lower bounds, on the other hand, represent the lowest feasible emissions that could come from a hectare in a particular land use class. The purpose for lower bounds is to ensure that some growth can be allowed in each grid square. Lower bounds are optional, but if they are not set, the linear programming package may arrive at a solution where no increase in emissions will be allowed in some of the squares.

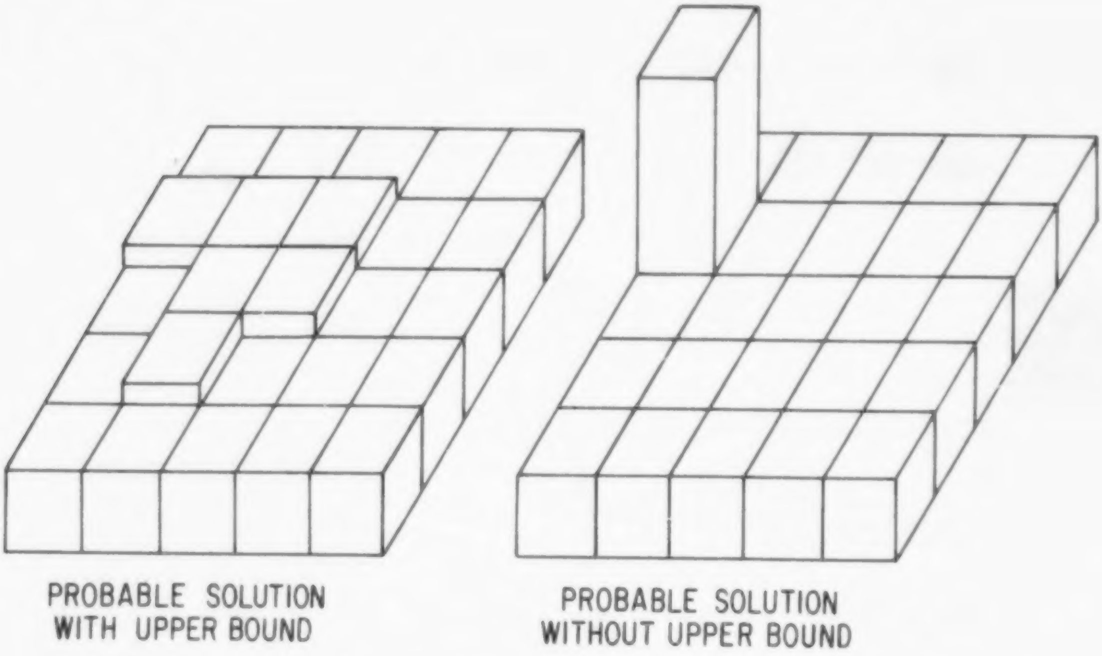


Fig. 90. Probable Effects of No Upper Bound (three-dimensional view)

The basic EDZ model assumes that upper and lower bounds will be constant throughout the region for a single land use class. However, in some instances upper and lower bounds may vary by both land use class and square. For example, if some grid squares are already highly developed, a lower bound of zero may be used to allow the option of restricting emission increases in these squares while still allowing for growth in all other squares in the region. If upper bounds varied by grid squares, the squares in the central or older parts of the region could be allowed higher EDLs to account for higher density of development and, therefore, less land for reducing emission densities. On the other hand, high EDLs in the outlying areas may be desirable to alleviate clustering in the central or core areas.

Thus, for each column in the matrix, there must be an upper bound; a lower bound may be included if you desire. Accurately setting these bounds is important since the linear program may be expected to find a solution where many land use classes will have permitted emissions set at the upper or lower bound. Bounds units are grams of emissions per second per hectare [(g/s)/ha].* The rest of the guidebook is written assuming that lower bounds have been set, but not setting lower bounds will not be a disadvantage later.

Finding the Bounds Coefficients

Upper and lower bounds coefficients are found with the aid of Worksheet 8, which was completed as part of Step 6. This worksheet plus a few calculations will reveal the upper and lower bounds for each land use class in the region. Since three manufacturing land uses are being considered (light, medium, and heavy), there will be three distinct upper bounds and, if used, three lower bounds. The bounds are calculated as follows:

Check with your state or local pollution control board to see if the sources listed on Worksheet 8 are currently complying with all present and known future emission control regulations. For those sources that are not in compliance, you must consult with the source operators and/or the state or local pollution control authority to estimate the emissions which will occur after compliance. These estimated emissions are to be in grams/second. The estimated emissions for sources not in compliance are to be divided by the area of the sources (in hectares) and substituted for the emission densities previously listed in the final column of Worksheet 8.

---

*For a further discussion of bounds, see Benesh et al. (1977).

The highest emission density for any one source within a land use class is the upper bound for that class. The upper bound for any one land use class is to be placed in each column of the linear program's coefficient matrix that describes lands belonging to the land use class. For example, assume that all the data for heavy manufacturing sources in a region are shown in Fig. 91 (Worksheet 8). The highest emission density for SO_2 in the right-hand column is the 37.50 (g/s)/ha for source 0014. This 37.50 represents the highest SO_2 emission rate per hectare that may be expected for a heavy manufacturing source. Therefore, for every column in the linear program matrix that describes heavy manufacturing lands, the SO_2 upper bound would be 37.50 (g/s)/ha. This process is repeated for light and medium manufacturing classes, and for all three classes for particulates. Figure 92 shows where to insert the upper bounds into the matrix.

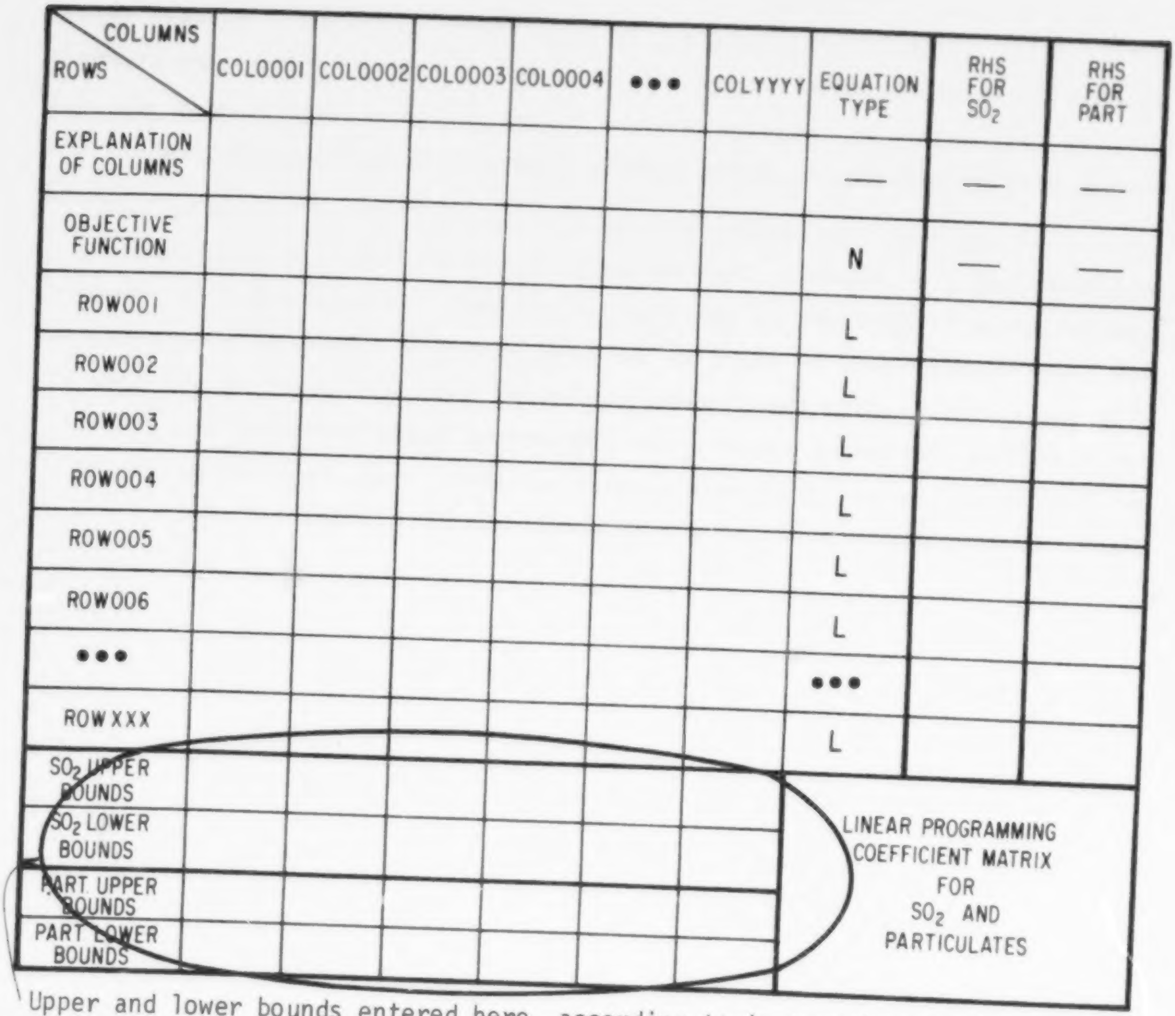
If lower bounds are set, the lowest emission density for any one source within a land use class is the lower bound for the class. The lower bounds are to be handled much like the upper bounds. For example, if the data in Fig. 91 were for all the heavy manufacturing sources in the region, then the SO_2 lower bound for all columns describing heavy manufacturing sources would be 15.0 (g/s)/ha. This figure would be inserted into the linear program coefficient matrix as shown in Fig. 92. If you decide not

WORKSHEET 8 (FOR STEP 6) FILLED OUT BY: ________	DATE ________	PG ___
EMISSION INVENTORY DATA FOR STEP 24		OF ___

POINT SOURCE NAME	POINT SOURCE I.D. NUMBER (FROM WORKSHEET 6)*	SIMPLIFIED LAND USE ZONING CLASS	EMISSION RATE OF POINT SOURCE (A) IN g/s		LAND AREA OF POINT SOURCE (B) IN ha	EMISSION DENSITY (A ÷ B) IN (g/s)/ha	
			SO_2	PART		SO_2	PART
EFFINGHAM	0014	M3	75.0	30.0	2.0	37.5	15.0
FAYETTE	0050	M3	150.0 ~~200.0~~	30.0 ~~50.0~~	5.0	30.0 ~~40.0~~	6.0 ~~10.0~~
MARION	0095	M3	150.0	20.0	10.0	15.0	2.0
WAYNE	0132	M3	65.0	—	3.0	21.2	—

*THE FIGURES PRESENTED HERE DO NOT CORRESPOND TO THE SAMPLE WORKSHEET 6 PRESENTED EARLIER.

Fig. 91. Sample Data for Illustrating Upper and Lower Bounds



COLUMNS / ROWS	COL0001	COL0002	COL0003	COL0004	•••	COLYYYY	EQUATION TYPE	RHS FOR SO_2	RHS FOR PART
EXPLANATION OF COLUMNS							—	—	—
OBJECTIVE FUNCTION							N	—	—
ROW001							L		
ROW002							L		
ROW003							L		
ROW004							L		
ROW005							L		
ROW006							L		
•••							•••		
ROWXXX							L		
SO_2 UPPER BOUNDS							LINEAR PROGRAMMING COEFFICIENT MATRIX FOR SO_2 AND PARTICULATES		
SO_2 LOWER BOUNDS									
PART UPPER BOUNDS									
PART LOWER BOUNDS									

Upper and lower bounds entered here, according to instructions in text.

Fig. 92. Filling in the Upper and Lower Bounds Rows of the Coefficient Matrix

to use lower bounds, you may either insert zeros or allow MPSX to automatically set the lower bounds at zero.

The upper and lower bounds you have calculated should now be checked to determine if they reflect current development practices. If past practice is little different from what can be expected in the future, the bounds should not be altered. But, if future sources are expected to have different per hectare emission densities, then changes must be made. For example, newly built sources may have distinctly different emission densities from older sources due to factors such as the trend toward single-level factories and larger lots. In addition, there may be significant differences between regulations designed for existing and new sources. If the effect of such trends and new regulations on emission density limits can be estimated, then the bounds must be adjusted to bring them in line with changing conditions.

You may wish to consider varying the upper and lower bounds by land use class <ins>and</ins> grid square. This variation might be desirable for reasons such as local differences in emission regulations. In this case, the upper and lower bounds would be found in the same manner as discussed above, except that instead of finding the highest and lowest emission densities per land use class for the entire region, the highest and lowest emission densities per land use class per grid square would be used. Thus, each column in the linear program matrix would have a different set of bounds.

STEP 22: CODE AND KEYPUNCH LINEAR PROGRAMMING INPUT DATA

SUMMARY

The input data for the MPSX linear programming package are coded and keypunched in Step 22. The card formats shown here are for use only in MPSX. (If you are using another linear programming package consult your user's manual to determine proper card format.) The data deck assembled in this step will be used in two linear programming runs, as explained in Step 23.

There are two substeps:

Step 25A: Code and Keypunch MPSX Data

Step 25B: Check Card Order

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

All the data required for keypunching are in the linear program coefficient matrix; before beginning Step 22, you must have completed Steps 1 - 11 and 14-21. See Fig. 93. Resource requirements are listed in Table 26.

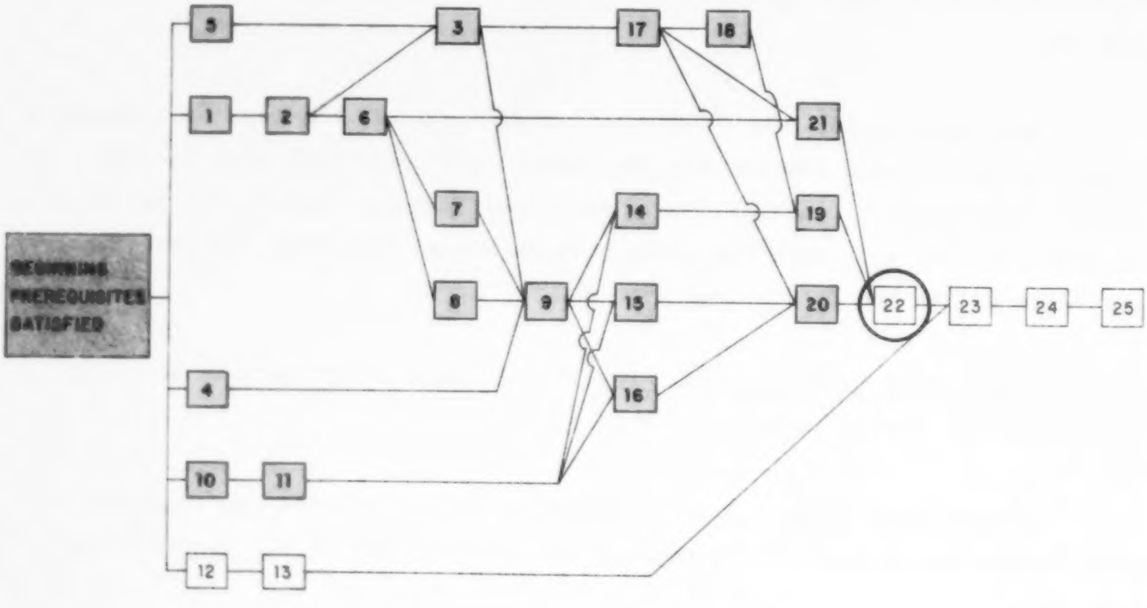


Fig. 93. Prerequisites for Step 22

Table 26. Resource Requirements for Step 22

Necessary Skills[a]	Necessary Data	Data Source	Necessary Hardware
Data Analysis Keypunching Possibly Programming	Completed LP Matrix	Steps 17 - 21	Keypunch

[a] First on list directs this step.

STEP 25A: CODE AND KEYPUNCH MPSX DATA

The MPSX card formats presented here must be followed; a complete card deck is illustrated in Fig. 94. All cards shown must be present and in the right order. The card formats, illustrated in Figs. 95 - 106, are discussed below.

Name Card. The name card, placed at the start of the data deck, simply labels the output. Its format is shown in Fig. 95.

Single Word Card: Rows. Each set of data cards is preceded by a card with a single word on it that tells the machine what type of cards to expect. There are five of these cards; the first one is the "rows card," shown in Fig. 96.

Rows Data Cards. The "rows data cards" indicate the type of constraint being applied to each row and the row names. The first rows data card describes the objective function row in the linear program coefficient matrix, as shown in Fig. 97. Each remaining rows data card describes one row (i.e., one receptor) in the matrix; see Fig. 98.

Single Word Card: Columns. Insert this card after the last rows data card; see Fig. 99 for format.

Columns Data Cards. The "columns data cards" provide the computer with values for each of the column and row coefficients in the matrix. See Fig. 100.

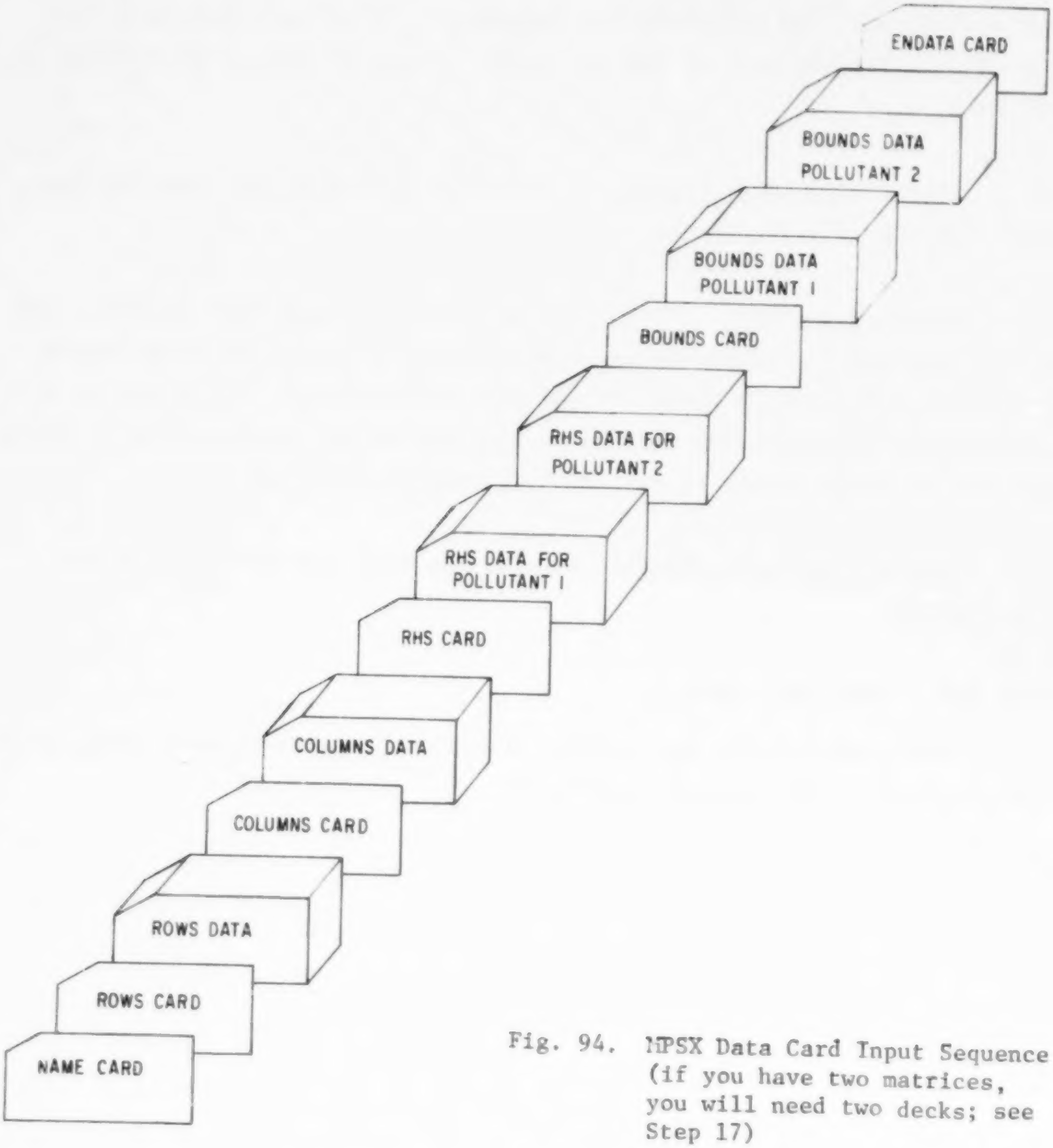

ENDATA CARD
BOUNDS DATA POLLUTANT 2
BOUNDS DATA POLLUTANT 1
BOUNDS CARD
RHS DATA FOR POLLUTANT 2
RHS DATA FOR POLLUTANT 1
RHS CARD
COLUMNS DATA
COLUMNS CARD
ROWS DATA
ROWS CARD
NAME CARD

Fig. 94. MPSX Data Card Input Sequence (if you have two matrices, you will need two decks; see Step 17)

Single Word Card: RHS. Insert this card after the last columns data card; see Fig. 101 for format.

Right-Hand-Side Data Cards. These cards provide the computer with the right-hand-side values for SO_2 or particulates for each row (receptor). There are two sets of RHS data cards -- one for SO_2 and one for particulates. Each set contains one card for each row in the matrix. Be sure to give each set a different "RHS identifier" in Columns 5 - 12 of each data card (see Fig. 102). The two sets of RHS data cards should be next to one another in the deck.

Single Word Card: Bounds. Insert this card after the last RHS data card; see Fig. 103 for format.

Bounds Data Cards. There are two sets of "bounds data cards" -- one for SO_2 and one for particulates. The formats for upper and lower bounds data cards are shown in Figs. 104 and 105, respectively. Place all the SO_2 bounds cards together, and all the particulate bounds cards together. These two sets of cards should be next to each other in the deck.

Single Word Card: ENDATA. This is the last card in the data deck. See Fig. 106.

STEP 25B: CHECK CARD ORDER

Check the deck to make sure it contains all the necessary cards in the correct order. Then proceed to Step 23.

COLUMN NUMBER	1-4	5-14	15-22	23-80
EXPLANATION	--	Leave Blank	Eight-letter name supplied by user.	Leave Blank
REQUIRED ENTRIES	NAME		(user-specified)	
TYPICAL COMPLETED CARD	NAME		EDZLPRUN	

Fig. 95. MPSX Name Card

COLUMN NUMBER	1-4	5-80
EXPLANATION	Identifies rows data cards	Leave Blank
REQUIRED CARD FORMAT	R0WS	

Fig. 96. MPSX Rows Card

COLUMN NUMBER	1-2	3	4	5-12	13-80
EXPLANATION	Leave Blank	Equation type	Leave Blank	Matrix row name	Leave Blank
REQUIRED CARD FORMAT		N		0BJFUNCT	

Fig. 97. MPSX Objective Function Card

COLUMN NUMBER	1-2	3	4	5-12	13-80
EXPLANATION	Leave Blank	Equation type	Leave Blank	Matrix row name. Start in Column 5.	Leave Blank
REQUIRED ENTRIES		L		(different on each card).	
TYPICAL COMPLETED CARD		L		RØW001	

Fig. 98. MPSX Rows Data Cards

COLUMN NUMBER	1-7	8-80
EXPLANATION	Identifies columns data cards	Leave Blank
REQUIRED CARD FORMAT	CØLUMNS	

Fig. 99. MPSX Columns Card

COLUMN NUMBER	1-4	5-12	13-14	15-22	23-24	25-36	37-80
EXPLANATION	Leave Blank	Matrix column name. Start in Col. 5.	Leave Blank	Matrix row name. Start in Col. 15.	Leave Blank	The coefficient found at the intersection of the matrix column and row listed. This is a 12-digit number (including decimal point). If this value is zero, you do not need a card for that column-row pair.	Leave Blank
REQUIRED ENTRIES		(varies)		(varies)		(varies)	
TYPICAL COMPLETED CARD		CØL001		RØW001		0000201.9631	

Fig. 100. MPSX Columns Data Cards

COLUMN NUMBER	1-3	4-80
EXPLANATION	Identifies RHS data cards	Leave Blank
REQUIRED CARD FORMAT	RHS	

Fig. 101. RHS Card

COLUMN NUMBER	1-4	5-12	13-14	15-22	23-24	25-36	37-80
EXPLANATION	Leave Blank	RHS identifier. Must be different for SO_2 and part. Start in Col. 5.	Leave Blank	Matrix row name. Start in Col. 15.	Leave Blank	Value in RHS column in matrix for row and pollutant listed.	Leave Blank
REQUIRED ENTRIES		(varies)		(varies)		(varies)	
TYPICAL COMPLETED CARD		RHSS02		R0W001		000000003.12	

Fig. 102. MPSX RHS Data Cards

COLUMN NUMBER	1-6	7-80
EXPLANATION	Identifies bounds data cards.	Leave Blank
REQUIRED CARD FORMAT	B0UNDS	

Fig. 103. MPSX Bounds Card

COLUMN NUMBER	1	2-3	4	5-12	13-14	15-22	23-24	25-36	37-80
EXPLANATION	Leave Blank	Type of bound.	Leave Blank	Identifies pollutant. Start in Col. 5.	Leave Blank	Identifies matrix column. Start in Col. 15.	Leave Blank	Value of upper bound for pollutant and matrix column listed (12-digit number).	Leave Blank
REQUIRED ENTRIES		UP		(user specified)		(varies)		(varies)	
TYPICAL COMPLETED CARD		UP		BNDS02		C0L001		0000431.0301	

Fig. 104. MPSX Upper Bounds Cards

COLUMN NUMBER	1	2-3	4	5-12	13-14	15-22	23-24	25-36	37-80
EXPLANATION	Leave Blank	Type of bound.	Leave Blank	Identifies pollutant. Start in Col. 5.	Leave Blank	Identifies matrix column. Start in Col. 15.	Leave Blank	Value of lower bound for pollutant and matrix column listed (12-digit number).	Leave Blank
REQUIRED ENTRIES		L0		(user-specified)		(varies)		(varies)	
TYPICAL COMPLETED CARD		L0		BNDS02		C0L001		000000001.00	

Fig. 105. MPSX Lower Bounds Cards

COLUMN NUMBER	1-6	7-80
EXPLANATION	Tells computer data deck is finished.	Leave Blank
REQUIRED CARD FORMAT	ENDATA	

Fig. 106. ENDATA Card

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STEP 23: MAKE LINEAR PROGRAMMING RUNS

SUMMARY

In Step 23 you will run the linear programming package. The instructions given here apply specifically to MPSX. If you are not using MPSX, consult your users manual.

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

Steps 1 - 22 must be completed before Step 23 is begun; see Fig. 107. Resource requirements are listed in Table 27.

RUN MPSX PACKAGE

The MPSX package needs to be run twice -- once to obtain SO_2 emission density limits and once to obtain particulate EDLs (both runs use the data deck assembled in Step 22). The "MPSX control language" that precedes the data deck determines which RHS and bounds data (that is, SO_2 or particulates) are used in each computer run. An experienced programmer familiar with the computer being used should be consulted to set up both the MPSX control language and the job control language. If you have a small linear

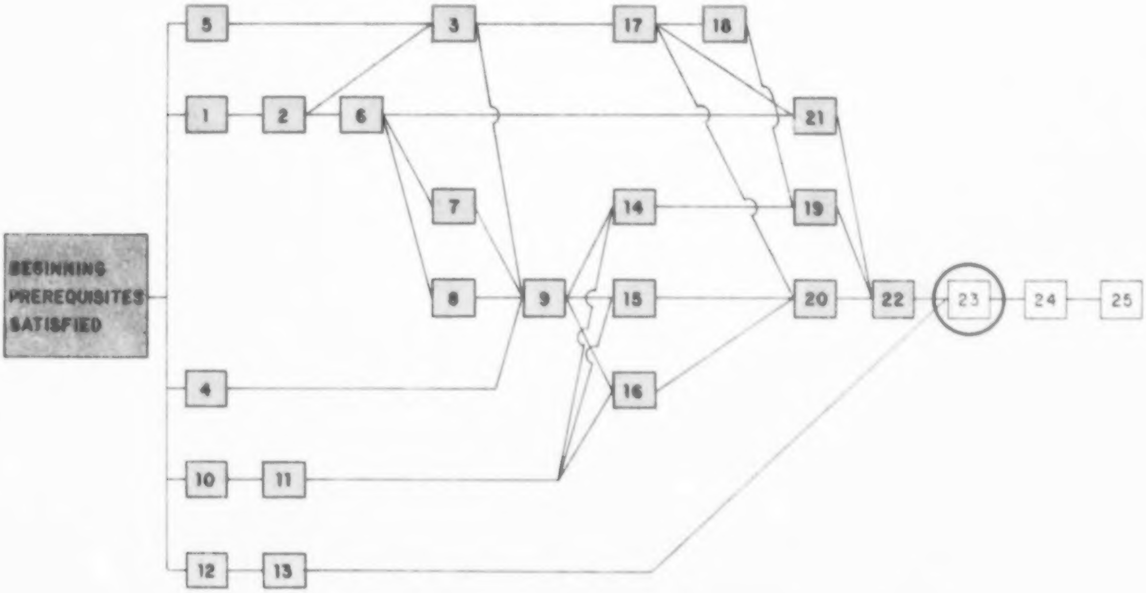


Fig. 107. Prerequisites for Step 23

Table 27. Resource Requirements for Step 23

Necessary Skills	Necessary Data	Data Sources	Necessary Hardware
Programming	MPSX Package Input Data Job Control Language	Step 12 Step 22 Local	IBM 360/370

programming problem or wish to include an SO_2-particulates feasibility constraint as discussed in Benesh et al. (1977), have a linear programming expert reformulate the problem so that you can combine the two runs into one.

The MPSX package may only be run on IBM 360 and 370 hardware.

STEP 24: ANALYZE LINEAR PROGRAMMING RUN RESULTS

SUMMARY

In Step 24 you will check the reasonableness of the EDLs for SO_2 and particulates set by the linear programming package. The discussion in Step 24 assumes the use of the basic EDZ model, whose approach is to maximize emissions throughout the metropolitan area.

Four substeps are involved:

Step 24A: Read EDLs on MPSX Output
Step 24B: Identify Any Infeasible Solutions
Step 24C: Map Linear Program Results
Step 24D: Check Maps for Reasonableness

Each substep in Step 24 must be done for both SO_2 and particulates, using the output of the two linear programming runs.

When Step 24D is completed, you will have set EDLs for each hectare of manufacturing-zoned land in your region. Emissions will have been maximized and air quality standards will not be violated. Therefore, the EDZ strategy described in the Introduction will have been completed, with implementation as the final step. If per-hectare EDLs are desired in your region, then Step 24 is the final step you need to follow. If you wish to use another emission quota strategy, such as floating zone emission quotas or jurisdictional emission quotas, then Step 25 must be followed.

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

Steps 1 - 23 must be completed before you begin Step 24, as shown in Fig. 108. Resource requirements are listed in Table 28.

STEP 24A: READ EDLs ON MPSX* OUTPUT

The linear program output is fairly long and not particularly easy to read for those with little experience in linear programming. The key to

---

*The following discussion applies to MPSX; consult your users manual if you are using a different linear programming package.

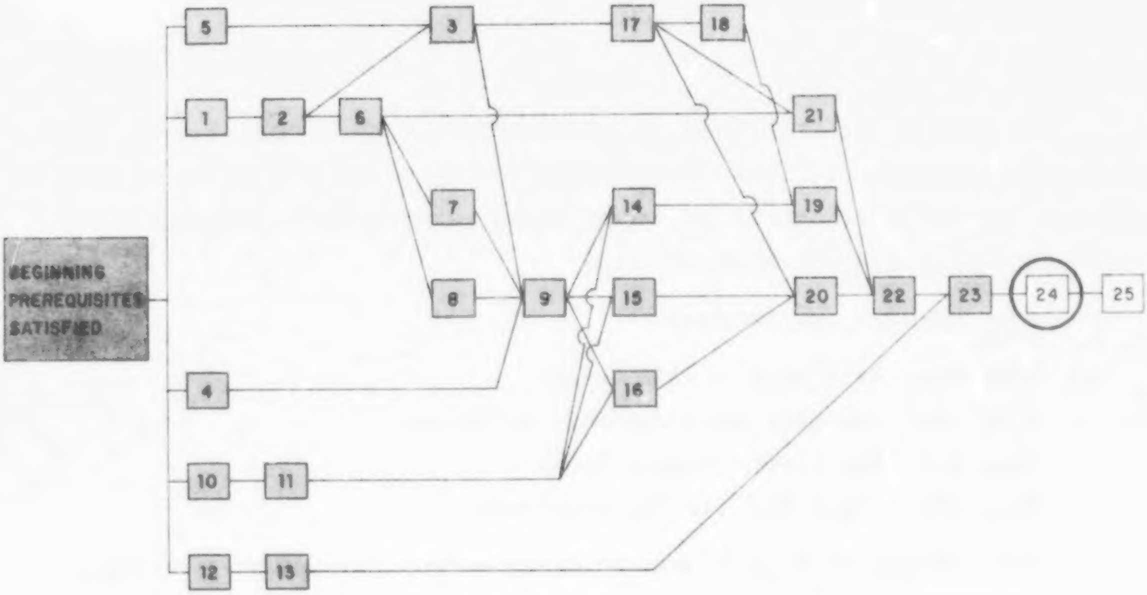


Fig. 108. Prerequisites for Step 24

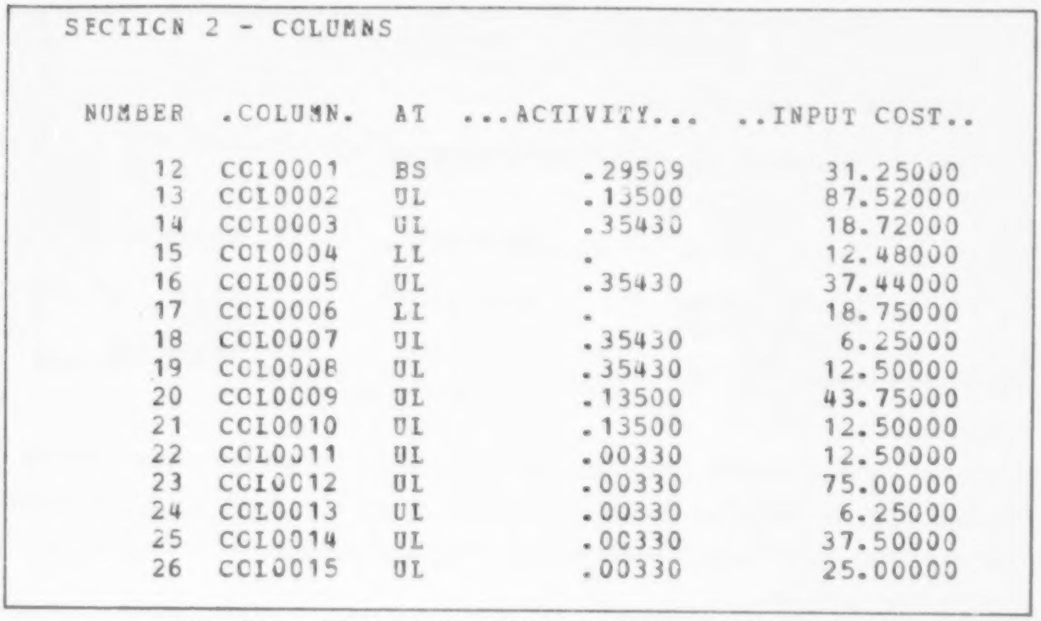
reading the output is to avoid being distracted by the "extra" information that the computer prints. To find the emission density limits [stated in terms of (g/s)/ha for each pollutant for each land use class in each grid square]:

1. Find the section of the MPSX output titled: SECTION 2 - COLUMNS (see Fig. 109).
2. Under SECTION 2 - COLUMNS, you will find a number of headings. Under the one labeled .COLUMN. are listed the column names used in the linear programming coefficient matrix.

Table 28. Resource Requirements for Step 24

Necessary Skills[a]	Necessary Data	Data Sources	Necessary Hardware
Land Use Planning Data Analysis Cartographic	Gridded General Regional Map	Steps 1 and 2	None
	Worksheet 2	Step 2	
	Worksheets 9 and 10	Step 7	
	Completed Linear Program Coefficient Matrix	Steps 18 - 21	
	Linear Program Output	Step 23	

[a] First on list directs this step.



```
SECTION 2 - COLUMNS


 NUMBER  .COLUMN.  AT   ...ACTIVITY...   ..INPUT COST..

     12  COL0001   BS         .29509         31.25000
     13  COL0002   UL         .13500         87.52000
     14  COL0003   UL         .35430         18.72000
     15  COL0004   LL         .              12.48000
     16  COL0005   UL         .35430         37.44000
     17  COL0006   LL         .              18.75000
     18  COL0007   UL         .35430          6.25000
     19  COL0008   UL         .35430         12.50000
     20  COL0009   UL         .13500         43.75000
     21  COL0010   UL         .13500         12.50000
     22  COL0011   UL         .00330         12.50000
     23  COL0012   UL         .00330         75.00000
     24  COL0013   UL         .00330          6.25000
     25  COL0014   UL         .00330         37.50000
     26  COL0015   UL         .00330         25.00000
```

Fig. 109. MPSX Output Showing EDLs and Other Data

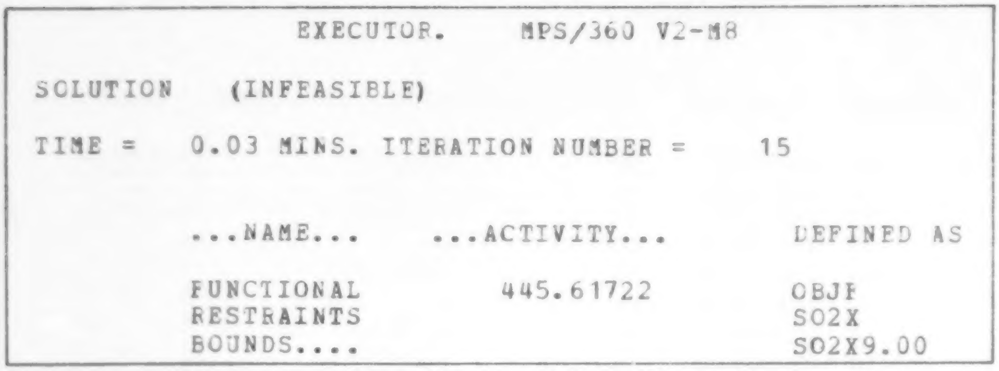
3. Under SECTION 2 - COLUMNS, you will also find a column labeled ...ACTIVITY... The values in this column are the per-hectare EDLs for each of the columns in the linear program coefficient matrix (remember that each matrix column represents one land use class within a grid square).

STEP 24B: IDENTIFY ANY INFEASIBLE SOLUTIONS

A linear programming problem, such as the one developed for EDZ, may have no feasible solutions. In EDZ, an infeasible solution occurs when the computer cannot find a configuration of EDLs that will not violate air quality standards. If you have an infeasible solution, you will find the words SOLUTION (INFEASIBLE) on one of the pages of the output. (This is illustrated in Fig. 110.)

Since Step 20 required that all right-hand-side coefficients be positive, there can be only one reason for the infeasible solution; the lower bounds are set too high. Infeasibility resulted from the computer setting all EDLs at the lower bound and yet still not being able to avoid violating standards at some receptors.

To solve this problem, decrease or eliminate at least some of the lower bounds. Decreasing the bounds will cut the chances for growth in



```
                    EXECUTOR.    MPS/360 V2-M8

SOLUTION    (INFEASIBLE)

TIME =    0.03 MINS. ITERATION NUMBER =     15


          ...NAME...     ...ACTIVITY...       DEFINED AS

          FUNCTIONAL         445.61722        OBJF
          RESTRAINTS                          SO2X
          BOUNDS....                          SO2X9.00
```

Fig. 110. Identifying an Infeasible Solution

emissions in some land use zoning classes and some areas, but this outcome is necessary if air quality standards are to be maintained. An experienced analyst familiar with linear programming can suggest ways of efficiently altering lower bounds.

STEP 24C: MAP LINEAR PROGRAM RESULTS

Map Total Potential Emissions*

Once the EDLs have been found, there will be a great temptation to map them. While EDL maps are important for transferring data from one office to another** (for example, from the regional group that set the EDLs to the local group that will administer them), and are important in political decision-making, they are not truly useful for finding out whether the linear program found a technically reasonable solution.

The reason why comparison of EDLs would not reveal whether the linear program arrived at a reasonable solution is that EDLs are dependent upon the number of hectares zoned for each land use class and the number of exempt sources in each grid square. The important technical consideration is whether there are large unexplainable fluctuations in total potential emissions per square kilometer. For example, the total potential emissions allowed in two adjacent grid squares may be identical, however, one square may have twice as much land area zoned in a particular zoning class as the other -- which may result in one square having an EDL for the zoning class that is only half as large as the other. In this case, EDLs would vary widely while total potential emissions in each grid square would be the same.

---

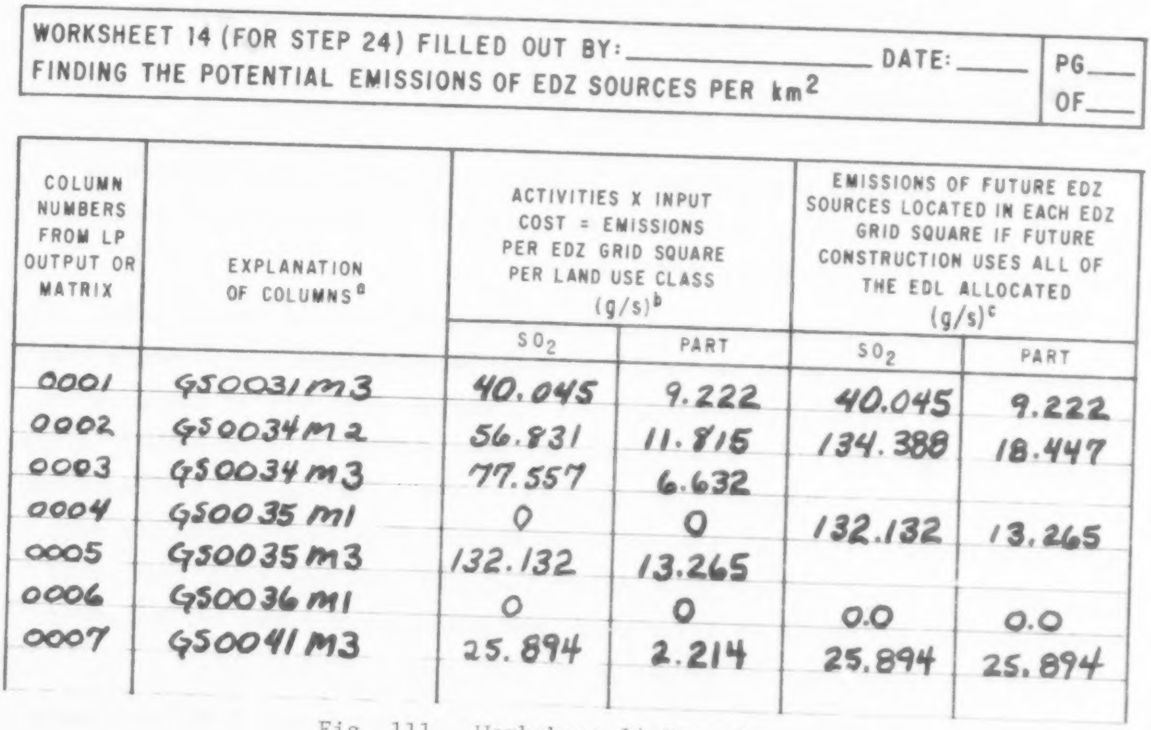
*Total potential emissions are those that would occur if all the land within an area had emissions that were at the maximum quantity allowed by the EDL plus the emissions from EDZ-exempt sources.

**Instructions for making EDL maps are in the second part of Step 24C.

The comparison of total potential emissions on a square kilometer basis will show the gradual differences and jumps in emissions between equal size areas that are caused by meteorological conditions, current emissions and exempt sources rather than by differences in zoning practice. To produce a map of total potential emissions, follow the procedure discussed below.

Complete Worksheet 14

The first step in mapping total potential emissions is to calculate the emissions of future EDZ sources located in each EDZ grid square that would result if future construction used all of the allocated EDL. This is done by completing Worksheet 14 (see Fig. 111).*



WORKSHEET 14 (FOR STEP 24) FILLED OUT BY:______________ DATE:_____ PG___ OF___
FINDING THE POTENTIAL EMISSIONS OF EDZ SOURCES PER km^2

COLUMN NUMBERS FROM LP OUTPUT OR MATRIX	EXPLANATION OF COLUMNS[a]	ACTIVITIES X INPUT COST = EMISSIONS PER EDZ GRID SQUARE PER LAND USE CLASS (g/s)[b]		EMISSIONS OF FUTURE EDZ SOURCES LOCATED IN EACH EDZ GRID SQUARE IF FUTURE CONSTRUCTION USES ALL OF THE EDL ALLOCATED (g/s)[c]	
		SO_2	PART	SO_2	PART
0001	G50031m3	40.045	9.222	40.045	9.222
0002	G50034m2	56.831	11.815	134.388	18.447
0003	G50034m3	77.557	6.632		
0004	G50035m1	0	0	132.132	13.265
0005	G50035m3	132.132	13.265		
0006	G50036m1	0	0	0.0	0.0
0007	G50041M3	25.894	2.214	25.894	25.894

Fig. 111. Worksheet 14 Example

---

*Full-page, blank worksheets for your use are provided in Appendix J.

The two left-hand columns of Worksheet 14 are completed by copying the column numbers and the corresponding entries in the "explanation of columns" row from the linear programming matrix. To fill in the "Activities x Input Cost" columns in Worksheet 14, refer to the linear program output discussed earlier (Fig. 109). Note that the entries in the .COLUMN. column on the output are the same as those in the first column of Worksheet 14. For each column number on the output (such as COL001), multiply the ...ACTIVITY... value by the ...INPUT COST... value and enter the result on Worksheet 14.

The final set of columns in Worksheet 14 ("Emissions of future EDZ sources...") contains the sum of the entries in the "Activities x Input Cost" columns for each grid square. For example, in Fig. 111 the emissions from the M1, M2, and M3 sources in grid square 00001 are added and the sum placed in the final columns (SO_2 and particulate emissions are summed separately). Some grid squares might contain only one EDZ source, as shown in Fig. 111 for grid square 00003. The data in Worksheet 14 will be used in Worksheet 15 (Fig. 112)

Complete Worksheet 15

Total the Emissions of Exempt Sources. The second step in mapping total potential emissions per square kilometer is to determine the total emissions of exempt point and area sources.

The total emissions in each EDZ grid square from the exempt point sources that you listed on Worksheet 10 must be calculated. This means that the location of every point source is to be mapped on a copy of the gridded general regional map (from Step 1) and its grid square location noted. After all sources have been mapped, use the grid square locations and the emissions data on Worksheet 10 to sum the projected emissions of the sources for each grid square. Place the resultant values (in g/s) into the appropriate rows in Column A of Worksheet 15 (list every EDZ grid square number on Worksheet 15, even if a square has no exempt point sources). See Fig. 112.

The total potential emissions in each EDZ grid square from the exempt area sources listed on Worksheet 9 also must be calculated. The area source portion of the emission inventory acquired in Step 6 includes a regional

WORKSHEET 15 (FOR STEP 24) FILLED OUT BY:__________ DATE ______ PG___

COMPARISON OF TOTAL EMISSIONS WITHIN EACH SQUARE KILOMETER OF___

EDZ GRID SQUARE NUMBERS	A EMISSIONS OF EXEMPT POINT SOURCES LOCATED IN EACH EDZ GRID SQUARE (g/s)[a]		B EMISSIONS OF EXEMPT AREA SOURCES LOCATED IN EACH EDZ GRID SQUARE (g/s)[b]		C EMISSIONS OF FUTURE EDZ SOURCES LOCATED IN EACH EDZ GRID SQUARE IF FUTURE CONSTRUCTION USES ALL OF THE EDL ALLOCATED (g/s)[c]		D TOTAL POTENTIAL EMISSIONS FROM EACH EDZ GRID SQUARE (g/s) D = A + B + C		E AREA OF EDZ GRID SQUARE (km^2)	F TOTAL EMISSIONS FROM EACH km^2 F = D ÷ E	
	SO_2	PART	SO_2	PART	SO_2	PART	SO_2	PART		SO_2	PART
00024	0	0	2.312	2.592	0	0	2.312	2.592	1	2.312	2.592
00025	0	0	3.761	4.063	0	0	3.761	4.063	1	3.761	4.063
00026	0	0	2.312	2.592	0	0	2.312	2.592	1	2.312	2.592
00027	0.0679	0.0065	3.761	4.063	0	0	3.828	4.067	1	3.828	4.067
00028	0	0	15.045	16.250	0	0	15.045	16.250	4	3.761	4.063
00029	0	0	3.841	4.271	0	0	3.841	4.271	1	3.841	4.271
00030	0	0	3.939	4.527	0	0	3.939	4.527	1	3.939	4.527
00031	6.000	0.116	3.841	4.271	40.045	9.222	49.886	13.609	1	49.886	13.609
00032	0	0	3.939	4.527	0	0	3.939	4.527	1	3.939	4.527
00033	0	0	15.755	18.108	0	0	15.755	18.108	4	3.939	4.527
00034	0	0	11.442	12.922	134.388	18.447	145.830	31.369	4	36.458	7.842
00035	7.090	1.320	12.699	14.276	132.582	13.265	152.371	28.861	4	38.093	7.215

[a] Exempt sources from Step 7 are mapped onto the general regional map and the emissions of the exempt sources are summed for each EDZ grid square. The results are placed in Column B. Use the gridded zoning maps from Step 2 to assist in locating the exempt sources.

[b] From the emission inventory (Step 6). Emissions from each emission inventory grid square are reallocated to the appropriate km^2 grids.

[c] From final column of Worksheet 14.

Fig. 112. Worksheet 15 Example

grid system that was used for dispersion modeling. The inventory lists the area source emissions for each such square. These emissions are to be reallocated from the emission inventory grid system to the EDZ grid system. This is done by assuming that area source emissions are uniform throughout a given emission inventory square. Each EDZ grid square covers a certain percentage of the land area of an emission inventory square. The quantity of emissions to be allocated from an emission inventory square to an EDZ grid square is equal to this percentage of the area source emissions in the emission inventory square. The area source emissions per EDZ grid square (g/s) are to be placed in Column B of Worksheet 15.

Estimate Total Emissions per Square Kilometer. The third step in this procedure is to complete Columns C - F of Worksheet 15. Column C is completed by copying the entries from the final set of columns on Worksheet 14.

Column D is completed by summing the values in Columns A, B, and C across each row. The values for Column E should be copied from Worksheet 2. Finally, Column F is filled in by dividing the Column D values by the appropriate Column E values.

The total potential emissions of each pollutant per square kilometer (recorded in Column F) should now be mapped onto copies of the gridded general regional map. Analysis of this map is discussed in Step 24D. A color-coded mapping system is recommended. Make two maps -- one for SO_2 and one for particulates.

Map Emission Density Limits

Once the regional map of total potential emissions per square kilometer has been made, the next step is to map the EDLs and see how they are distributed. You will need six copies of the gridded regional map produced in Step 2.

First, map the light manufacturing EDLs for SO_2 and particulates (the ...ACTIVITY... entries from the linear programming output, identified by their COL XXX designations and the references in Worksheet 14) onto two of the gridded general regional maps. The mapping may be simplified by dividing the EDLs into five or seven classes and color-coding each class.

Second, map all the medium manufacturing EDLs onto the two other gridded general regional maps, and map all the heavy manufacturing EDLs onto the last two maps.

STEP 24D: CHECK MAPS FOR REASONABLENESS

Maps of Total Potential Emissions

If the EDL-setting process has worked, you should find few unexplainable "large" differences or jumps in total per-square-kilometer emissions between adjacent squares. There may be gentle undulations which occur from differences in local meteorology, but no large changes unless:

- A particular EDZ grid square currently has no sources located within it, and has no land zoned for manufacturing use. This condition would cause a "valley" if surrounding squares have several sources and/or land zoned for industrial classes (see Fig. 113).
- A particular EDZ grid square contains many exempt sources while adjacent squares contain few or none. Even if all the squares had the same number of hectares zoned for the

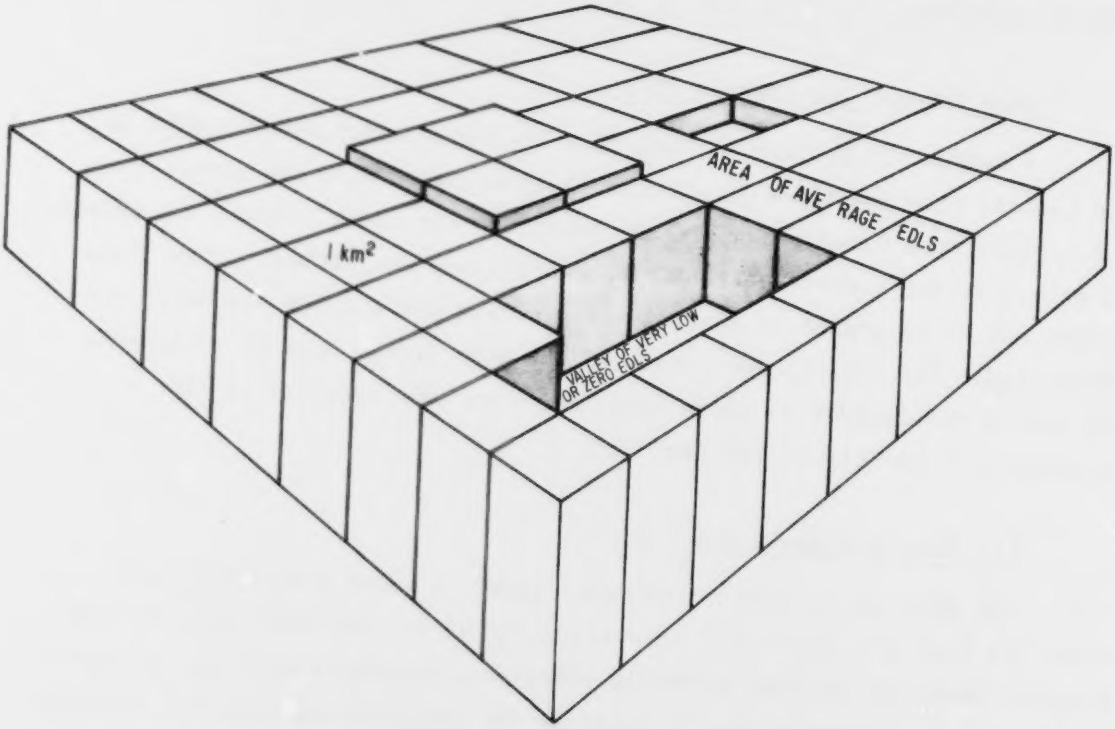


Fig. 113. Three-Dimensional View of an Emission "Valley"

same manufacturing classes, the square with more exempt sources would show higher total emissions. This is due to the upper bound placed on EDLs; only so much pollution may come from a square if the square contains no exempt sources. (This "peaking" condition is shown in Fig. 114.)

- The region contains more than one PSD class. In this case, the emissions on either side of the PSD boundary may be expected to vary due to the difference in air quality standards being applied; see Fig. 115 for a view of this situation.

If adjacent grid squares have similar land use zoning, similar exempt sources, and similar air quality standards -- and have large unexplainable differences in total potential emissions -- then actions may have to be taken to smooth the total emissions. Some of the possible actions are outlined in the following discussions of EDL patterns.

Maps of Emission Density Limits

Several patterns that may be expected in the EDLs generated by the linear program are discussed below. These patterns are not to be considered problems.

High Fringe, Low Central EDLs

A common EDL pattern is high EDLs in fringe areas and low EDLs in the central city and close-in suburbs if existing sources are exempt from EDZ. Since more development already exists in the central area, the expectation is that the current pollutant concentrations are higher. Thus, less growth can be tolerated in central areas before air quality standards are threatened. The anticipated effect of the high fringe EDLs is to promote new source development in these areas and thus make best use of the assimilative capacity of the air.

All EDLs at Upper Bound

All EDLs may be set at the upper bound in cases where the upper bound has been set very low. This situation means that even with all new sources using the maximum allowable emissions, standards will not be violated. If the region wishes to increase the emissions to possibly increase the opportunities for economic growth, then upper bounds could be raised.

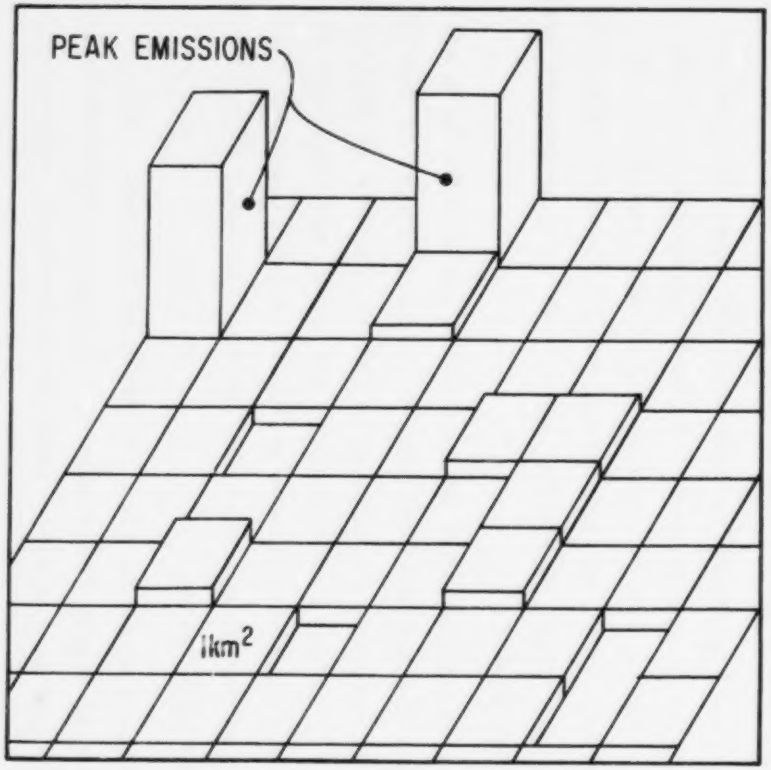

PEAK EMISSIONS
1km^2

Fig. 114. Three-Dimensional View of Emission "Peaks"

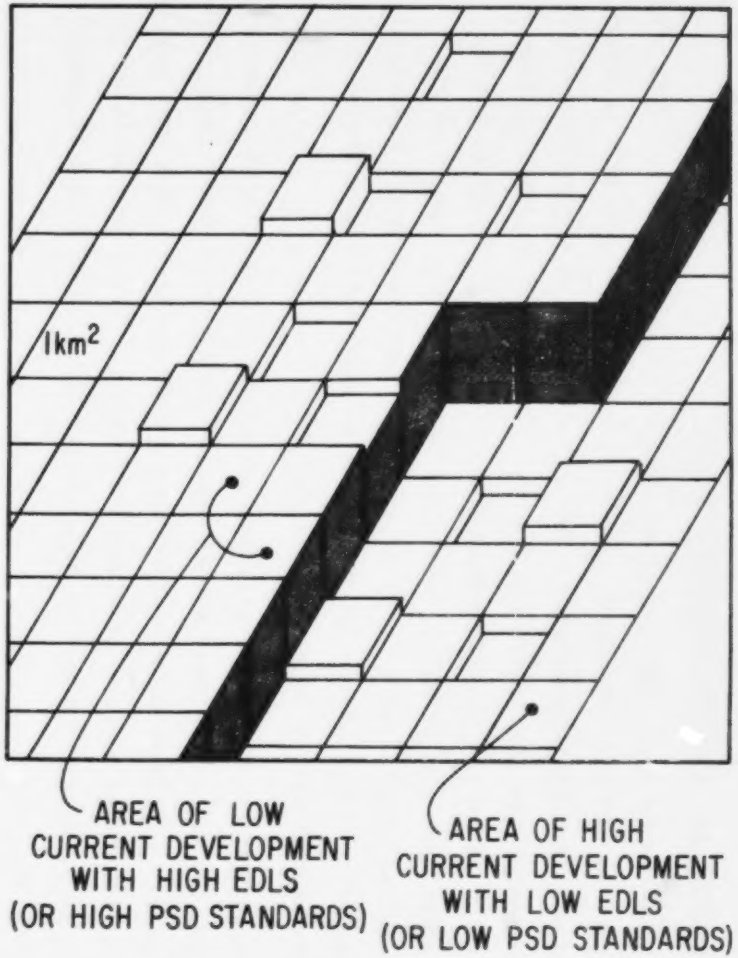

1km^2
AREA OF LOW CURRENT DEVELOPMENT WITH HIGH EDLS (OR HIGH PSD STANDARDS)
AREA OF HIGH CURRENT DEVELOPMENT WITH LOW EDLS (OR LOW PSD STANDARDS)

Fig. 115. Three-Dimensional View of Border Region of Changing Emissions

Most EDLs Set at Upper or Lower Bounds

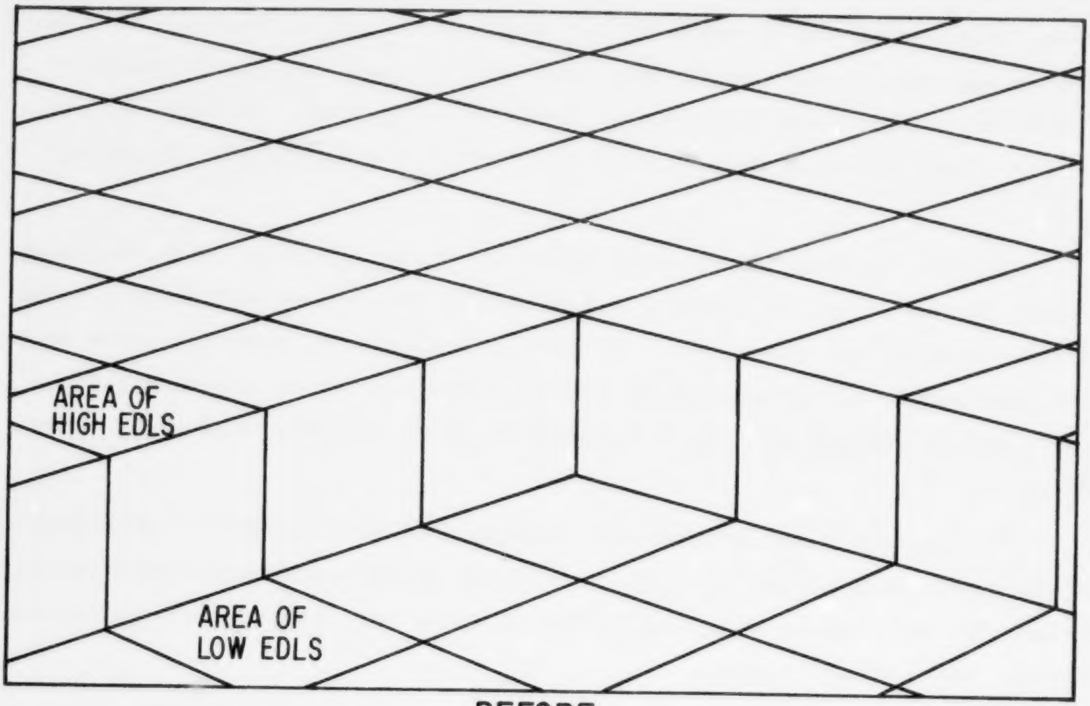
This is to be expected in regions with built-up core areas. The program will set the EDLs in areas near the center as low as possible to avoid violations of air quality standards. Since the inputs to the program do not allow solutions below the lower bounds, the lower bounds are where close-in EDLs are set. Since the objective function of the basic EDZ model was to maximize emissions, the fringe areas (which have much less impact on the receptors in the central area -- in other words, there are small transfer coefficients for fringe sources to central area receptors) have their emissions maximized by having EDLs at the upper limit.

This situation may cause political problems if individuals argue over the location of the upper/lower bound boundary relative to their land. This is particularly likely to be a problem when an EDL boundary line cuts across a piece of land owned by one individual or company. There are at least six acceptable adjustments that may be made if the upper/lower bound situation causes friction.

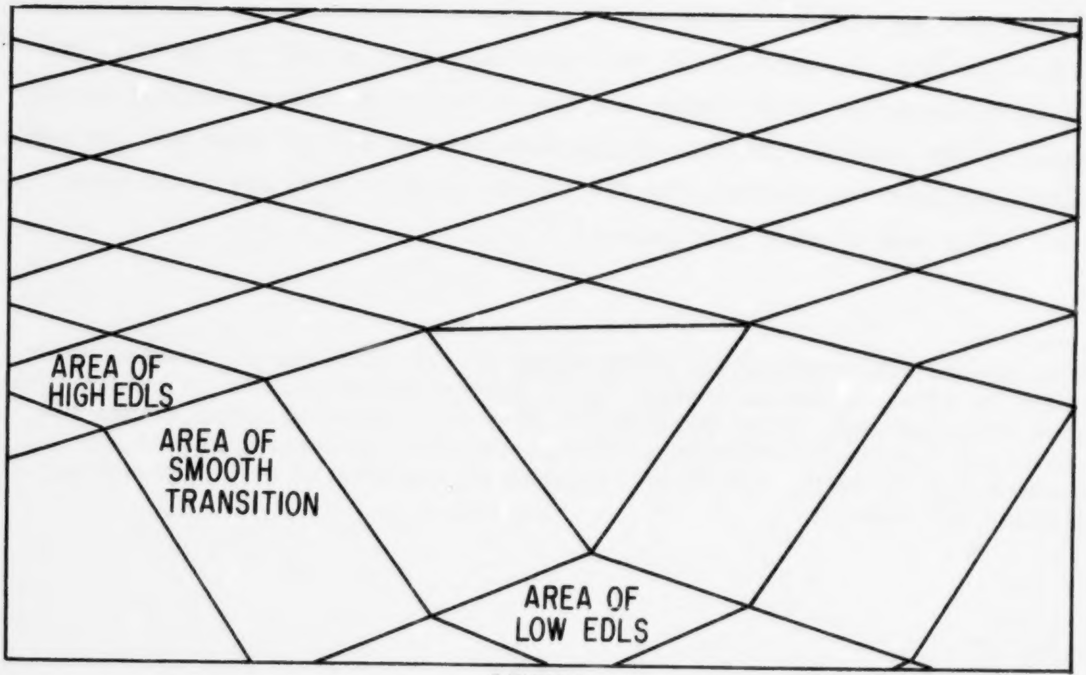
First, since the EDLs have been set objectively and the grid system's location is essentially a "line drawing problem," if legal counsel agrees with the legality of this EDZ gridding methodology, the complaints may be treated in a manner similar to the treatment of such complaints in traditional land use zoning. While this may not be politically expedient, it would maintain the credibility of the solution given by the model and avoid setting new precedents that might be harmful later. Be sure to consult legal experts before taking any action.

Second, the EDLs of single-owner parcels which are divided by a grid square boundary may have the EDL over the entire parcel averaged to make it uniform throughout. For example, if Bilgewater Industries owns 10 hectares, all of which is zoned for medium manufacturing, and three hectares have an EDL of 6 (g/s)/ha and the other seven have an EDL of 4 (g/s)/ha, then the EDL for the entire 10-hectare parcel could be set at $[(3 \times 6) + (7 \times 4)]/10 = 4.6$ (g/s)/ha at Bilgewater's option.

Third, the procedure shown in Fig. 116 could be followed. Here, political expediency would temper the desire for maximizing emissions since the EDLs would be graduated at the upper/lower bound boundary. Those squares


AREA OF
HIGH EDLS
AREA OF
LOW EDLS

BEFORE


AREA OF
HIGH EDLS
AREA OF
SMOOTH
TRANSITION
AREA OF
LOW EDLS

AFTER

Fig. 116. Three-Dimensional View of Gradually-Changing EDLs

at the lower bound would remain at the lower bound, while those at the upper bound along the boundary would have their EDLs changed to make a smooth transition in EDLs from the lower to upper bound squares. In this way, no parcels of land directly next to each other would have radically different EDLs.

Fourth, if EDLs in one grid square are very high while those in nearby squares are very low, it could be a function of the number of hectares zoned in a particular land use class. If there is a desire to make EDLs more uniform, the number of hectares zoned for each land use class within a grid square can be changed and the EDLs reallocated to (or from) the newly zoned land.*

Fifth, the linear program may be rerun using a "proximity constraint" as discussed in Benesh et al. (1977). The proximity constraint would require the program to produce an optimal solution while not allowing much variation between adjacent grid squares.

Sixth, the upper and lower bounds may be altered for specific grid squares and the linear program rerun to create a more uniform distribution of EDLs. Altering the bounds will only work when most or all of the EDLs are set at the upper or lower bounds and the direction of change desired is consistent. For example, if EDLs within some squares are too high and the upper bound constraint is binding, the EDL can be lowered by lowering the upper bound being used in that grid square.

---

*This action will require the involvement of the local zoning commission or board to effect a zoning change. If a zoning change can not be agreed upon, then this approach is not practical. Note that rezoning would change the objective function coefficients used in the linear programming and may necessitate rerunning the linear programming package if extensive zoning changes are made.

STEP 25: FORMULATE THE EDL STRATEGY

SUMMARY

In Step 25 you will develop a land used based emission strategy (LUBES) by extending the methodology presented in Steps 1 - 24. If you select an EDZ strategy, this is quite simple. Three other applications of emission density limits also are discussed briefly.*

One of the following substeps should be completed depending on the emission quota strategy chosen:

Step 25A: The Emission Density Zoning (EDZ) Approach
Step 25B: The Jurisdictional Emission Quotas (JEQ)** Approach
Step 25C: The District Emission Quotas (DEQ) Approach
Step 25D: The Floating Zone Emission Quotas (FZEQ) Approach

Before trying any of these approaches, consult legal counsel to check on equal protection and due process problems which may arise from these strategies.

PRELIMINARY STEPS AND RESOURCE REQUIREMENTS

The decision on whether to use EDZ, JEQ, DEQ, FZEQ or another land use based emission stragegy should have been made before the EDL-setting procedure began. Research on the characteristics of each approach should have been done at the time. As shown in Fig. 117, Steps 1 - 24 must be completed before Step 25 is begun. Resource requirements are listed in Table 29.

STEP 25A: THE EMISSION DENSITY ZONING (EDZ) APPROACH (emission rates allocated per hectare of land)

Emission Density Zoning. This phrase, "emission density zoning," has been used to cover a widely varying group of different land use-based air quality management strategies. For example, Bosselman, et al., uses the term to encompass both emission allocation planning and district emission quotas. For our purposes here, emission density zoning (EDZ) will be defined as an air quality maintenance strategy

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*The discussion in Steps 25A - 25D is based on Brail, 1975a.
**Often called emission allocation planning (EAP) in the literature.

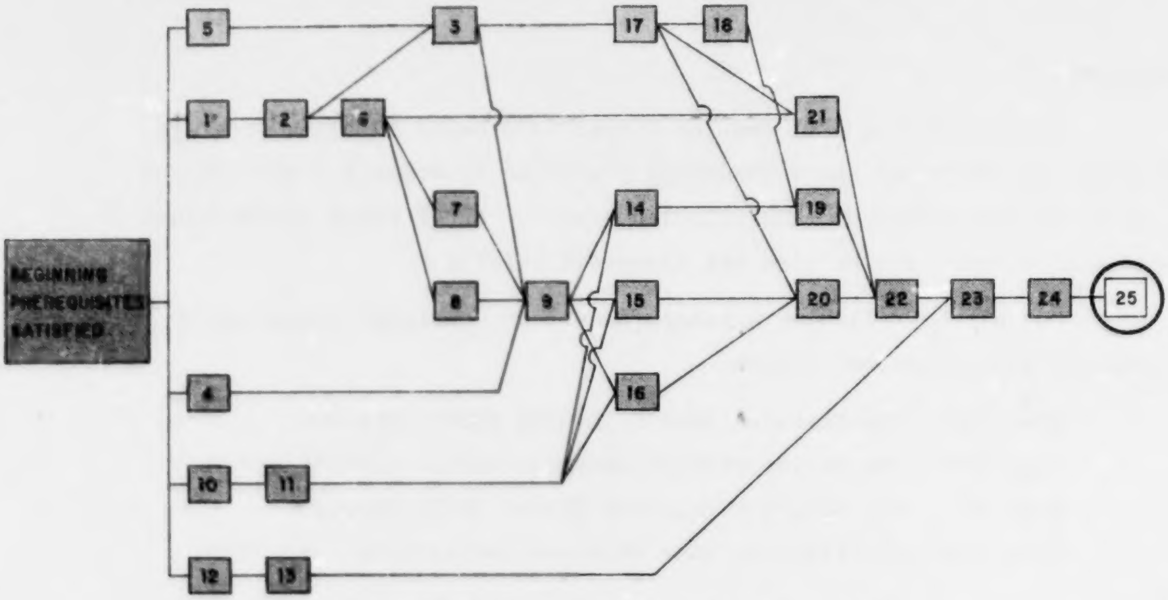


Fig. 117. Prerequisites for Step 25

which requires that emissions of a pollutant be limited to prescribed levels for a selected unit area. Thus, EDZ might be more properly labeled unit area emission quotas.

The pollutant limit would be developed in terms of an amount per unit area per time period specific to a particular land use category. For example, an EDZ regulation might specify that heavy industrial land uses seeking to construct in a municipality must emit no more than two tons of particulates per acre of lot size per year. Hence, a 100 acre establishment classified as heavy industry would have to certify that it would emit less than 200 tons of particulates yearly before being allowed to construct. (Brail, 1975a)

Table 29. Resource Requirements for Step 25

Necessary Skills[a]	Necessary Data	Data Sources	Necessary Hardware
Land Use Planning Data Analysis Administration and Implementation	Regional Maps EDLs	Step 2 Step 24	Cartographic Files

[a] First on list directs this step.

This approach is the conception of EDZ explained in the guidebook Introduction. The idea is to set an EDL for each hectare of land in a region based solely on the outcome of the dispersion modeling and linear programming analysis. No political factors are considered beyond the number of hectares of land zoned in a particular land use class within an arbitrary grid square. In the case of EDZ, Step 25 is little more than a mirror of Step 24. The only additional instruction is to administer the system in some legally defensible, fair, and equitable manner. The level of government and the form of the administering agency are beyond the scope of this guidebook, but conceivably the system could be administered at the state, regional, or local level.

STEP 25B: THE JURISDICTIONAL EMISSION QUOTAS (JEQ) APPROACH (emissions allocated to each political jurisdiction for distribution within its borders, subject to reasonable guidelines)

> Emission Allocation Planning (Jurisdictional Emission Quotas). The most broadly conceived of the emission limitation techniques centers on placing lids on the amount of pollutants emitted within defined political boundaries, including municipalities, counties and states. While Bosselman, et al., has referred to this jurisdictional emission quota concept as emission density zoning this strategy has been usually referred to as emission allocation procedures or emission allocation planning (EAP). California has been the most advanced in its thinking about emission allocation planning, where a ceiling would be established on the total amount of emissions in an air basin and this total allocated to sub-areas within the basin. Extrapolating from the California experience, it becomes apparent that EAP is a flexible tool which allows local political jurisdictions a great deal of latitude in dealing with air quality problems.
>
> Emission allocation planning does allow the local decision-makers a great deal of flexibility. It is this flexibility which is appealing and, at the same time, potentially dangerous. The allocation of a quota in itself provides no guidance to the local area, and EAP may be such a loosely-drawn concept that it would be ineffectual in maintaining air quality. Regulations would have to be developed to mandate compliance by jurisdictions with the quotas assigned, and might include mandatory review of land use and transportation plans as well as monitoring of zoning and subdivisions regulations, including variances. There is no doubt that EAP has appeal as an air quality maintenance

> strategy. Some recent unpublished research work done for EPA has advised its use in maintenance areas. (Brail, 1975a)

If you are using a JEQ strategy, sum the EDLs for all hectares within a local jurisdiction to give the entire jurisdiction a single emission ceiling. Each political unit could split up its allocation in any legal way it chooses, provided it does not exceed its ceiling. For larger jurisdictions, emission quotas would have to be set for subareas such as individual grid squares within the jurisdiction to avoid violation of air quality standards. Unlike EDZ, JEQ does not completely eliminate the possibility of local violations of air quality standards since source clusters could occur within a jurisdiction. If review procedures were developed to oversee source siting, then JEQ could become a very useful air management tool.

STEP 25C: THE DISTRICT EMISSION QUOTAS (DEQ) APPROACH (emissions allocated to subareas of jurisdictions)

> District Emission Quotas. A step down from EAP is a strategy which limits the amount of pollutants to be emitted during some time period from a planning district within a jurisdiction. Thus, the amount of emissions generated by an industrial zone of 100 acres might be limited to no more than 200 tons of particulates per year. Once the emission limitations had been established for a particular district, new polluting sources would only be allowed if the quota had not been exceeded.
>
> Different kinds of districts, e.g., residential, commerical, and industrial, would be permitted varying amounts of emissions. Through this strategy, "hot spots" could be avoided and air quality possibly maintained. Since there has been relatively little study into this technique, it is not exactly clear how it would operate.
>
> The land use planning implications of the district emission quotas (DEQ) concept would center on the juxtaposition of different activities. The development of a heavy industrial district, with accompanying relatively high emission ceilings, would mean that residential districts be located away at an appropriate distance and wind direction. It is by no means clear that planners have the freedom to simply locate different land uses in districts so that there are few air quality problems. However, consider the simple case where DEQ is used for indirect source control. A district could be developed around the indirect source, and an emission lid attached. Such a lid could be

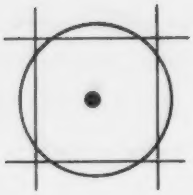
> used to keep future emissions from the existing indirect source, plus any additional sources, within the pre-established ceiling. (Brail, 1975a)

As you can see, there are great similarities between DEQ and JEQ, and so, the extension of the EDL methodology is basically the same. Sum the EDLs for all hectares within the districts and allocate the total emissions to each new source in an equitable manner. Delineation of the districts depends on the local communities.

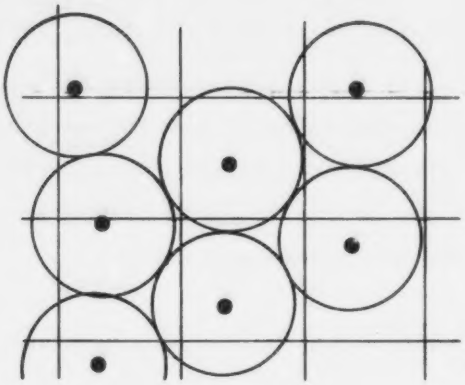
STEP 25D: THE FLOATING ZONE EMISSION QUOTAS (FZEQ) APPROACH (emissions within a certain radius of a new point source cannot exceed a specific amount)

> Floating Zone Emission Quotas. As the name implies, the "floating zone emission quota" (FZEQ) concept refers to limitations on pollutants generated within an area of specified size which can be drawn about any specific location within the metropolitan area. For example, air quality maintenance objectives might include a limiting of emissions to 2,000 tons of particulates within any one square mile of the air quality maintenance area. The use of floating zone emission quotas is best seen when evaluating the impact of a new industrial facility. Given this 2,000 ton per year limitation on particulates within a square mile, then a circle, containing an area of a square mile, could be placed about the proposed location of the new industry, the centroid of the circle. Thus, if the new industry is estimated to emit 200 tons of particulates per year, then the one square mile surrounding the industry must have existing total emissions of no more than 1,800 tons of particulates. The FZEQ concept was developed for use in Jefferson County, Kentucky. (Brail, 1975a)

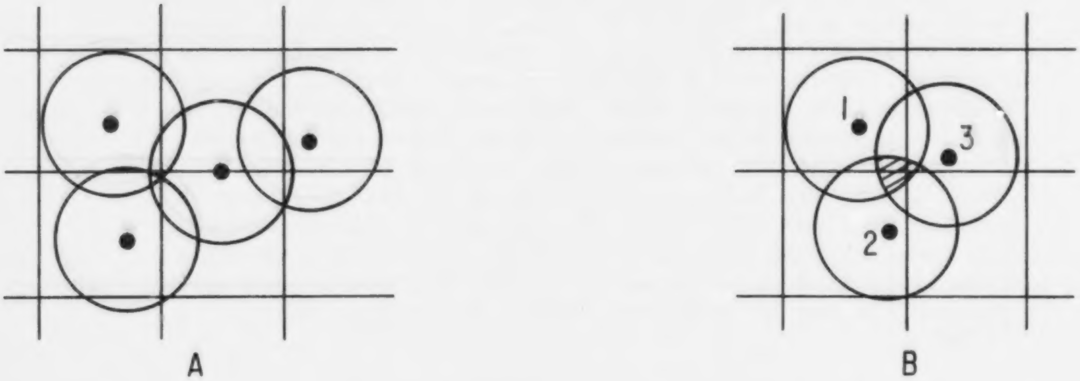
As stated above, in FZEQ, a new source wishing to locate in an area provides the FZEQ implementing authority with a statement of how much pollutant the source will emit. After determining the emissions from all other sources located in the area where the source wants to locate, the FZEQ authority permits or denies construction based on whether the total emissions near the proposed site are above or below some objectively-set limit for the area (see Fig. 118). The challenges in FZEQ are (1) determining the size of the area around the source that should be considered in the analysis (e.g., the radius of the circle placed around the new source), (2) determining the quantity of emissions to be allowed in the area, and (3) keeping good records



FZEQ: ONE SOURCE
● is a source. The circle has a 1.2 km radius. The source is allowed to use the entire quota within the circle.



FZEQ: MULTIPLE SOURCES, TANGENTIALLY ARRANGED
● is a source. Each source is located such that the quota used by each is independent of the others.



FZEQ: MULTIPLE SOURCES WITH OVERLAPPING RADII Primary Question: Can sources be located in this manner and yet not violate standards? The main problem would be in the shaded area in "B." Assume source 1 used all of the quota within its radius. Can Source 2 use up all the quota within its radius while assuming the EDL within the 1 and 2 intersection equals zero and yet still not violate the standards within the intersection area? Does the problem intensify when source 3 comes in? Answers to these questions should be determined before FZEQ is attempted. In any event, FZEQ will require a sophisticated and up-to-date accounting system to assure that the quotas are not assigned more than once.

Fig. 118. Floating-Zone-Emission-Quota Situations

so that the implementing authority knows the emission quota remaining in each area of the region.

The EDL process can do little to help in the political decision of determining the size of the area to be studied, but it can help a great deal in determining allowable emissions once the sizes have been determined.

To help set FZEQ quotas, all that need be done is to produce the EDL map of Step 24, locate the future position of the new source on the map, and sum the per hectare EDLs within a certain radius of the new source to provide a figure showing the total amount of emissions that may be allowed in the area. The total emissions for the area are compared to the planned emissions of the new source. If planned emissions plus existing emissions are below the quota for the area within the radius, then the source is permitted to build. If not, the source will have to find another location.

APPENDIX A: GLOSSARY

This glossary presents definitions of terms specific to EDZ and selected aspects of air pollution control and land use planning. Many of these terms have precise legal meanings that are beyond the scope of this guidebook. The intent here is to give a summary of each term to help you quickly interpret the word's general meaning and usage. The sources of definitions not written by the guidebook authors are listed at the end of Appendix A.

Adjacent Points: Two corner-point feasible solutions [to a linear programming problem] are said to be adjacent if the line segment connecting them lies on the edge of the boundary of the feasible region. (14)

Air Pollution: The presence of unwanted material in the air in sufficient amount and under such circumstances as to harm plants or animals, or interfere with comfort, health, or welfare of persons, or with full use and enjoyment of property. (23)

Air Quality: Air quality involves the degree of concentration of undesirable air pollutants. (21)

Air Quality Control Region: An area designated by the federal, state, or local government where two or more communities - either in the same or different states - share a common air pollution problem. (8)

Air Quality Criteria: Compilation of knowledge of the relationships between concentrations of air pollutants and their adverse effects. (2)

Air Quality Maintenance Area (AQMA): Those areas (counties, urbanized areas, standard metropolitan statistical areas, etc.) which, due to current air quality and/or projected growth rate, may have the potential for exceeding any national standard within the subsequent 10-year period. (11)

Air Quality Run: A type of dispersion model run used in setting EDLs. The purpose is to generate source-to-receptor transfer coefficients used by the linear programming model.

Air Quality Standards: The prescribed level of pollutants in the outside air that cannot be exceeded legally during a specified time in a specified geographical area. (8)

Ambient Air: The portion of the atmosphere, outside buildings, accessible to the general public.

Area Source: An aggregate of a large number of small individual pollution sources, including transportation sources. This is a general definition; area source is legally and precisely defined in federal regulations. (8)

Assimilative Capacity: The absolute limit of the ability of a body of water or air to purify itself of pollution before the environment breaks down. (8, 9)

Atmospheric Dispersion Model: See dispersion model.

Attainment: See nonattainment area.

Automatic Compliance Status: As used in the guidebook, an existing source given automatic compliance status is assigned an emission density limit equivalent to its pre-EDZ emission density, assuming the source is in compliance with all other relevant air quality standards.

Background Level: For air pollution, amount of pollutants in ambient air due to natural or extraregional man-made sources.

Baseline: A line in a land survey that serves as the origin for computations. In EDZ, a meridian (line of longitude) that is used as the starting point or line for a coordinate system. (24)

Base Map: A map having only essential outlines and used for the plotting or presentation of specialized data of various kinds. (24)

Basic EDZ Model: A formulation of EDZ wherein total emissions within a region are maximized on the theory that maximizing emissions will maximize opportunities for economic growth.

Calibration: Model calibration is a technique for improving the predictive capability of a general air quality simulation model within some region of interest, based on the comparison of model predictions with actual air quality measurements. The term model calibration refers specifically to the determination of the coefficients of a linear equation relating observed with predicted values. In CDMQC the determination is done by standard linear least-squares regression methods. (5)

Cartesian Coordinates: In a plane, a point can be located by its distances from two intersecting straight lines, the distance from one line being measured along a parallel to the other line. The two intersecting lines are called axes (X axis and Y axis). (17)

Class I, II, III: These terms that classify land areas based on air quality considerations have been given precise legal meanings by the Clean Air Act Amendments of 1977. Information relating to these classes should be received from the state air pollution control authority or a U.S. EPA regional office.

Code: As used in the guidebook, to write data onto a "coding form" preparatory to keypunching. The form shows the exact column where each character is to be punched.

Coefficient: A number or factor put before and multiplying another. (20)

Column, Computer Card: A vertical line of punch positions on a card where holes may be punched that will represent data. (20)

Column and Rows Sections (of linear programming matrix): An A-matrix in linear programming. In an EDZ linear programming coefficient matrix, the part of the matrix that describes the air quality contribution made by each EDZ source to each EDZ receptor per unit emission density.

Compile: The act of using a compiler, or what a compiler does.

Compiler: A special program read into the computer that translates human-oriented computer languages into machine language. Some compilers are capable of detecting syntax errors while compiling. (A syntax error consists of errors in spelling, logic, etc.) (10)

Compiler Diagnostic Message: A note produced while a computer is compiling a program which says that there is an error or may be an error in the program. (16)

Composite Zoning Maps: As used in EDZ, maps that show zoning inside and outside of incorporated areas, generally on a county-wide or regional basis.

Comprehensive Plan: A comprehensive plan is an official public document adopted by a local government as a policy guide to decisions about the physical development of the community. (12)

Concentration: For air pollutants, the total mass (usually in micrograms) of the suspended particles contained in a unit volume (usually one cubic meter) at a given temperature and pressure; sometimes, the concentration may be expressed in terms of total number of particles in a volume (e.g., parts per million); concentration may also be called the "loading" or the "level" of a substance. (2)

Constraint: A restriction on available options. Something that does not allow complete freedom. (14)

Controlled Emissions: Emissions that are lessened by means of pollution-removing equipment, or conversion to cleaner fuels and processes. In the guidebook, refers to emissions resulting from a source after compliance with applicable air pollution control regulations.

Coordinate: Any one of a set of numbers used in specifying the location of a point on a line, in space, or on a given plane or other surface. (20)

Corner Point (feasible solution): In linear programming, a feasible solution that does not lie on any line segment connecting two other feasible solutions. See feasible solution. (14)

Criteria, Air Quality: See air quality criteria.

Disk Storage: A computer data storage device that uses magnetic recording on flat rotating disks. (15)

Dispersion Model: An urban air quality simulation or dispersion model is a numerical technique or methodology, based on physical principles, for estimating pollutant concentrations in space and time as function of the emissions distribution and the attendant meteorological and geophysical conditions. (18)

District Emission Quotas (DEQ): A variation of emission allocation planning where the strategy is to limit the amount of pollutants to be emitted during some time period from a planning district within a jurisdiction. (4)

Easting: The X coordinate in a Cartesian coordinate system such as the Universal Transverse Mercator Coordinate System. Also, the north-south line running through the coordinate. (13)

EDZ Grid Origin: A point, southwest of a region setting emission density limits, that serves as the southwest corner of the EDZ grid system. All points on the grid system which are east and north of the EDZ grid origin have positive values. The values of the coordinates at the EDZ grid origin need not be 0,0.

EDZ Grid System: A grid system used for the air quality run of the dispersion model and for allocating emission density limits.

EDZ Receptor Point: A point used in the dispersion model as a location for calculating air quality.

EDZ-Relevant Land Use Class: A land use class for which emission density limits are set.

EDZ Source: One EDZ-relevant land use class within one EDZ grid square. An EDZ source refers to the entire area of land in a land use class, not to individual parcels.

Effective Stack Height: The height from the ground at which the centerline of a plume becomes horizontal.

Emissions: All the substances discharged into the air from a stack, vent, tail pipe, or other source. This term is generally used in regard to discharges into the air. (23, 8)

Emission Allocation Planning (EAP): Also called "jurisdictional emission quotas." An air pollution control strategy that places lids on the amount of pollutants emitted within defined political boundaries, including municipalities, counties, and states. Also see Step 25. (4)

Emission Density Limit (EDL): A ceiling set on the amount of air pollution that may be legally emitted per unit of time per unit of land area.

Emission Density Zoning: A type of air pollution control regulation in which the maximum legal rate of emission of an air pollution is based on location, land area, land use zoning, and air quality constraints. (19)

Emission Inventory: A list of air pollutants emitted into a community's atmosphere, in amounts (usually tons) per day, by type of source. Related information such as stack characteristics are also included in an emission inventory. The emission inventory is basic to the establishment of emission standards. (8)

Enabling Legislation [or Enabling Statute]: Any statute enabling persons or corporations to do what before they could not. It is applied to statutes which confer new powers. (3)

Environment: The sum of all external conditions and influences affecting the life, development and, ultimately, the survival of an organism. (8)

Exempt Source: As used in the guidebook, a pollution source that is not controlled by EDZ and is not assigned an EDL.

Exit Gas Velocity: The speed (generally m/s) at which stack gases leave a stack.

Extraterritorial Jurisdiction: (a) The authority of local governments in some states to regulate land use for a specified distance beyond their corporate boundaries. (b) The area outside of the boundaries of a local government over which the local government has authority to regulate land use.

Feasible Region: In linear programming, if the problem is graphed, the feasible region is the area wherein all the feasible solutions may be found. (14)

Feasible Solution: In linear programming, a solution for which all the constraints are satisfied. (14)

Floating Zone Emission Quotas (FZEQ): An air pollution control strategy that limits the pollutants generated within an area of specified size which can be drawn about any specific location. Also see Step 25. (4)

Fugitive Dust: Solid airborne particulate matter emitted at or near ground level from any source other than a stack, flue, or control system.

Gaussian Dispersion Models: Any of a set of dispersion models that assume that pollutants disperse in a normal distribution. See dispersion model. (22)

Grid Axes: The perpendicular lines running north and east from a grid system origin.

Grid Cell (or square): A single square in a grid system.

Grid System: An array of grid squares.

Hot Spot: A place where there are high concentrations of pollutants. Often hot spots are caused by the congestion of a few heavy polluters.

Index: A table of computer words or fields containing addresses of records located in file storage. (20)

Infeasible Solution: In linear programming, a solution for which one of the constraints is not satisfied.

Joint Frequency Function (Distribution): A statistical summary showing the percentage of total time when two or more variables (here wind speed, direction, and stability) coincide. (6)

Jurisdictional Emission Quotas (JEQ): See emission allocation planning.

Land Use: The activity on a parcel of land.

Land Use Class: Related land uses placed into a single group. (24)

Land Use Plan: A document showing the intended uses of land. Generally without force of law, the land use plan is supposed to be the basis for the zoning ordinance.

Linear Programming: Sometimes called optimum programming or mathematical programming. The analysis of problems in which the linear function of a number of variables is to be maximized (or minimized) when those variables are subject to a number of constraints in the form of linear inequalities, or the solution of these problems. This technique is not to be confused with computer programming, although problems using the technique may be programmed on a computer. Linear programming is most likely to be feasible when the quantity to be optimized, sometimes called the objective function, can be stated as a mathematical expression in terms of the various activities within the system, and when this expression is simply proportional to the measure of the activities, i.e., is linear and when all the restrictions are also linear. (20)

Mass: The property of a body, commonly taken as a measure of the amount of material it contains, that causes it to have weight in a gravitational field. The mass of an object is constant, while weight varies with gravity. (24)

Mass Per Unit Time Basis: A means of measuring air pollution by way of measuring the mass emitted during a specified period of time, such as g/s.

Matrix: A rectangular array of numbers subject to mathematical operations, such as addition, multiplication, and inversion, according to specified rules. (20)

Meridian: A great circle on the surface of the earth passing through the poles and any given place. (24)

Mixing Height: The height (generally in meters) from the ground at which there is a somewhat stable layer of air. The mixing height is as high as pollutants will rise.

Mobile Source: A moving source of air pollution, such as an automobile. (8)

Monitoring: Periodic or continuous determination of the amount of pollutants present in the environment. (8)

Nonattainment Area: The term nonattainment area means, for any air pollutant, an area that is shown by monitored data or which is calculated by air quality modeling,... to exceed any national ambient air quality standard for such pollutant. (7)

Nonconforming Use: At the time a land use zoning ordinance is originally adopted, there are, in almost every district, some uses that existed before the ordinance was adopted, which do not conform to the use regulations or the dimensional regulations for the district. These are known as nonconforming uses. Other such uses are created from time to time by amendments to the zoning ordinance. (12)

Normalizing (UTM Coordinates): Placing the entire EDZ grid system on a common set of axes such that all lines within the grid are straight and perpendicular and based on the UTM coordinate system. Normalizing is needed only in regions containing a UTM grid junction.

Northing: The Y coordinate in a Cartesian coordinate system such as UTM; also the east-west line running through the coordinate. (13)

Objective Function: The function of the independent variables whose maximum or minimum is sought in an optimization problem. (20)

Offset Policy: A policy that permits in certain nonattainment areas the construction and operation of new sources of air pollution if existing sources reduce emissions to compensate for the new source's emissions. (19)

Optimal Solution: An optimal solution is a feasible solution that has the most favorable value for the objective function. (14)

Packaged Program: A standardized computer program supplied by a software manufacturer to perform specific functions.

Parameter: (a) A quantity, in a mathematical calculation, that may be assigned any value; (b) a constant or a variable in mathematics that remains constant during some calculation; (c) a definable characteristic of an item, device, or system. (20)

Particulates (or Particulate Matter): Finely divided solid or liquid (except uncombined water) particles in the air or in an emission. Particulates include dust, smoke, fumes, mist, spray and fog. (8 & 1)

Parts Per Million (ppm): The unit commonly used to represent the degree of pollutant concentration where the concentrations are small. Larger concentrations are given in percentages. In air, ppm is usually a volume/volume ratio. (8)

Plume: The emissions from a flue or chimney. (8)

Plume Rise: The height a plume attains once it is emitted from a stack. Plume rise is affected by velocity of the effluents at the top of the stack, temperature of effluents, diameter of the stack opening, wind speed, temperature of air, wind shear with height, and atmospheric stability. (22)

Point Source: In air pollution, a stationary source of a large individual emission. This is a general definition; point source is legally and precisely defined in federal regulations. (8)

Pollution, Air: See air pollution.

Receptor: See EDZ receptor point.

Run: One performance of a program on a computer. (20)

Simplex Method: The general method for solving linear programming problems. By using the method, one can find the point at which the objective function is maximized or minimized if there is one. (14)

Simulation: The representation of physical systems and phenomena by computers, models or other equipment; an imitative type of data processing in which a computer program is used as a model of some entity, such as the process of air pollutant dispersion. When information enters the computer to represent the factors of process, the computer produces information that represents the results of the process. Also see dispersion model. (20)

Solution: In linear programming, any specification of values for decision variables, whether feasible or not. (14)

Source: In EDZ, an emitter of sulfur dioxide or particulates.

Source-by-Source Basis: Pollution controls operate on a source-by-source basis if the controls are placed on each individual producer of pollution.

Source Contribution Table: For each receptor, the CDMQC program prints out the computed concentration (or, optionally, percentage) of each pollutant that arrives at the receptor from each source. This list is a source contribution table. (5). Also see Transfer Coefficient.

Source, Existing: A source operating at the time an EDZ regulation goes into effect.

Source, Small: A source not listed in an emission inventory.

Stability Class: A classification system has been developed to determine the relative "calmness" of the atmosphere at a given location. Wind speed, solar radiation, and cloud cover are among the variables used to produce the six classes, A-F. A stability class is any one of the six. (22)

Stack Gas: The emissions coming from a stack, including all air contaminants, water vapor, and air.

Stack Height: The distance, above the ground, at which a pollutant is emitted from a source.

Standard Metropolitan Statistical Area (SMSA): One of many metropolitan regions of the U.S. which fit designated criteria set up by the Department of Commerce for the purpose of collecting statistical data. (1)

Stationary Source: A pollution emitter that is fixed, rather than moving. (8)

State Implementation Plan (SIP): A plan written by a state under authority of the Clean Air Act (and its Amendments) for the control of air pollution.

Sulfur Dioxide (SO_2): A heavy, pungent, colorless gas formed primarily by the combustion of fossil fuels. SO_2 damages the respiratory tract as well as vegetation and materials and is considered a major air pollutant. (8)

Total Potential Emissions: As used in the guidebook, total potential emissions are the emissions (in g/s) that would occur if all the land within a grid square had controlled emissions that were at the maximum allowed by the EDL plus emissions (in g/s) from EDZ-exempt sources.

Transfer Coefficient: An index, or indication, of the amount of air pollution traveling from a source to a receptor. Transfer coefficients in EDZ are generally based on unrealistically high quantities of emissions so that the group performing EDZ will not overlook the effects of each source on each receptor. Also see Source Contribution Table.

Universal Transverse Mercator (UTM): The name given to a type of Cartesian coordinate system using the Mercator map projection; the UTM system is used extensively in military mapping. (13)

UTM Grid Junction: A meridian where two UTM grid zones meet. (13)

UTM Grid Zones: A 6° wide north-south strip of the earth with a unique baseline from which UTM coordinates are measured. The baselines are the equator and the meridian in the center of each zone which is given an easting value of 500,000 meters; thus the easting value of UTM coordinates within any one zone run from approximately 250,000 meters to 750,000 meters. Northings in the northern hemisphere vary from 0 (equator) to somewhat less than 10 million meters. (13)

Variance: Sanction granted by a governing body for delay or exception in the application of a given law, ordinance or regulation. (8)

Variable: A quantity that may assume any one of a specified set of values. (24)

Zone: To partition (a city, borough, or township) by ordinance into zones or sections reserved for different purposes (as residence, business, or manufacturing or combinations of these) and governed by appropriate building regulations (as the height and area of all structures). (24)

Zoning Class: A land use category in a zoning ordinance. The three largest classes are residential, commercial, and industrial, which may be further subdivided into the single family dwelling class, the two-family class, retail business class, etc. (12)

Zoning District (Zone): A land area where specified land uses are authorized by a zoning ordinance.

Zoning Map: A map included in a zoning ordinance that outlines the specified land areas in which various land uses are authorized.

Zoning Ordinance: A legal document showing the lawful uses of land and various other land-use-related regulations within a jurisdiction, enacted to protect the health, safety and welfare of the public.

Zoning Survey: In EDZ, a survey to find the areas of lands zoned in EDZ-relevant land use classes within individual grid squares.

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APPENDIX B: ABBREVIATIONS*

A	Simplified zoning classification for area sources
AQCR	Air Quality Control Region
AQDM	Air Quality Display Model (a dispersion model)
AQMA	Air Quality Maintenance Area
CDM	Climatological Dispersion Model
CDMQC	An improved version of the CDM
DEQ	District Emission Quotas
EAP	Emission Allocation Planning
EDL	Emission Density Limit
EDZ	Emission Density Zoning
EPA	Environmental Protection Agency
FZEQ	Floating Zone Emission Quotas
JFF	Joint Frequency Function (meteorological)
K	A computer term meaning 1024 bytes of computer memory space; also means degrees Kelvin. Meaning must be taken from context.
LUBES	Land Use Based Emission Strategy
M1	Light manufacturing zoning district
M2	Medium manufacturing zoning district
M3	Heavy manufacturing zoning district
MCD	Minor Civil Division
MPSX	Mathematical (linear) Programming System Extended
NAAQS	National Ambient Air Quality Standard
NCC	National Climatic Center
NEDS	National Emissions Data System, an EPA data management system
PSD	Prevention of Significant Deterioration
RHS	Right Hand Side
SAROAD	Storage and Retrieval of Aerometric Data, an EPA data system
SMSA	Standard Metropolitan Statistical Area
SO	Sulfur oxide
SO_2	Sulfur dioxide
SO_x	Any oxide of sulfur
SSU	Stratified Systematic Unaligned (dot pattern)
UTM	Universal Transverse Mercator

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*Abbreviations for metric and selected English units of measure are given in Appendix C.

x	(1) any variable. (2) a horizontal axis in a coordinate system. (3) the downwind direction from a stack.
y	(1) any variable. (2) a vertical axis in a coordinate system. (3) the ground level axis perpendicular to the downwind direction from a stack.
z	(1) any variable. (2) a third axis, beginning at the origin, at right angles to the plane formed by x and y axes. The z axis creates a three-dimensional space from a two-dimensional one. (3) the axis beginning at the center of a stack rising upward to infinity.

APPENDIX C: METRIC UNITS AND CONVERSIONS

This appendix offers a brief explanation of the metric system of measurement and selected conversion factors. The conversion factors listed here are those you are most likely to need in order to convert data in English units into the metric units needed for the dispersion and linear programming models. Additional conversion factors may be found in standard technical reference books.

If you are totally unfamiliar with the metric system, you should consult a reference book; such a book should be available from most libraries. Briefly, basic metric units of measurement are: the meter for length, the kilogram for mass, and degrees Celsius for temperature. The metric system is based on multiples of ten, with prefixes used to indicate the "size" of the unit, as shown by the following examples:

- micro- (μ) means one-millionth
    1 micrometer (μm) - 0.000001 meter (m)
    1,000,000 μm = 1 m
- milli- (m)* means one-thousandth
    1 millimeter (mm) = 0.001 m
    1,000 mm = 1 m
- centi- (c) means one-hundredth
    1 centimeter (cm) = 0.01 m
    100 cm = 1 m
- kilo- (k) means one thousand
    1 kilometer (km) = 1000 m
    0.001 km = 1 m

There are, of course, many other metric prefixes; the four listed above are some of the most common.

Following are selected metric/English conversion factors for units of:

- length
- area
- velocity and flow rate
- weight and mass
- concentration
- temperature
- emission rates and emission density limits

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*An "m" standing alone means "meter." An "m" in front of another unit means "milli," as in mg (milligram) or mm (millimeter).

LENGTH

1 foot (ft) = 0.3048 meter (m)
1 m = 3.281 ft

1 mile (mi) = 1.609 kilometers (km)
1 km = 0.6215 mi

AREA

1 square mile (mi^2) = 2.590 square kilometers (km^2) or 259.0 hectares (ha)*
1 km = 0.3861 mi^2
1 hectare = 0.003861 mi^2

1 acre = 0.004046 km^2 or 0.4046 ha
1 km^2 = 247.1 acres
1 ha = 2.471 acres

VELOCITY AND FLOW RATES

1 foot per minute (fpm or ft/min) = 0.00508 meters per second (m/s)
1 m/s = 196.8 ft/min

Emission inventories sometimes provide a "flow rate" for stack gas in ft^3/min. To find the gas' exit velocity in m/s:

- divide ft^3/ min by 60, giving ft^3/s
- divide ft^3/s by the stack area [which is 3.142 times the stack radius (in feet) squared], giving ft/s
- divide ft/s by 3.281 (the number of feet in a meter), giving m/s.

WEIGHT AND MASS

1 pound (lb) = 453.6 grams (g)
1 g = 0.002205 lb

CONCENTRATION

1 part per million SO_2 by volume (ppm) = 2860 micrograms SO_2 per cubic meter ($\mu g/m^3$)**
1 $\mu g/m^3$ SO_2 = 0.00034965 ppm SO_2

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*1 ha = 0.01 km^2 = 10,000 m^2.
**At 0° Celsius and atmospheric pressure of 760 mm mercury.

TEMPERATURE

Fahrenheit temperature in °F to Celsius temperature in °C:
subtract 32 from °F, then multiply by 5/9
°C to °F: multiply °C by 9/5, then add 32

Celsius temperature in °C to Kelvin temperature in K: add 273 to °C
K to °C: subtract 273 from K

EMISSION RATES AND EMISSION DENSITY LIMITS

1 pound/hour (lb/hr) = 0.1260 grams/second (g/s)
1 g/s = 7.9365 lbs/hr

1 pound/day (lb/day) = 0.00525 g/s
1 g/s = 190.5 lbs/day

1 (lb/hr)/acre = 0.3114 (g/s)/hectare
1 (g/s)/hectare = 3.211 (lbs/hr)/acre

1 (lb/day)/acre = 0.01298 (g/s)/hectare
1 (g/s)/hectare = 77.04 (lbs/day)/acre

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APPENDIX D: MIXING HEIGHT MAPS*

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*Maps reproduced from Holzworth, G.C., *Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States*, U.S. Environmental Protection Agency, Office of Air Programs Publication No. AP-101 (Jan. 1972).

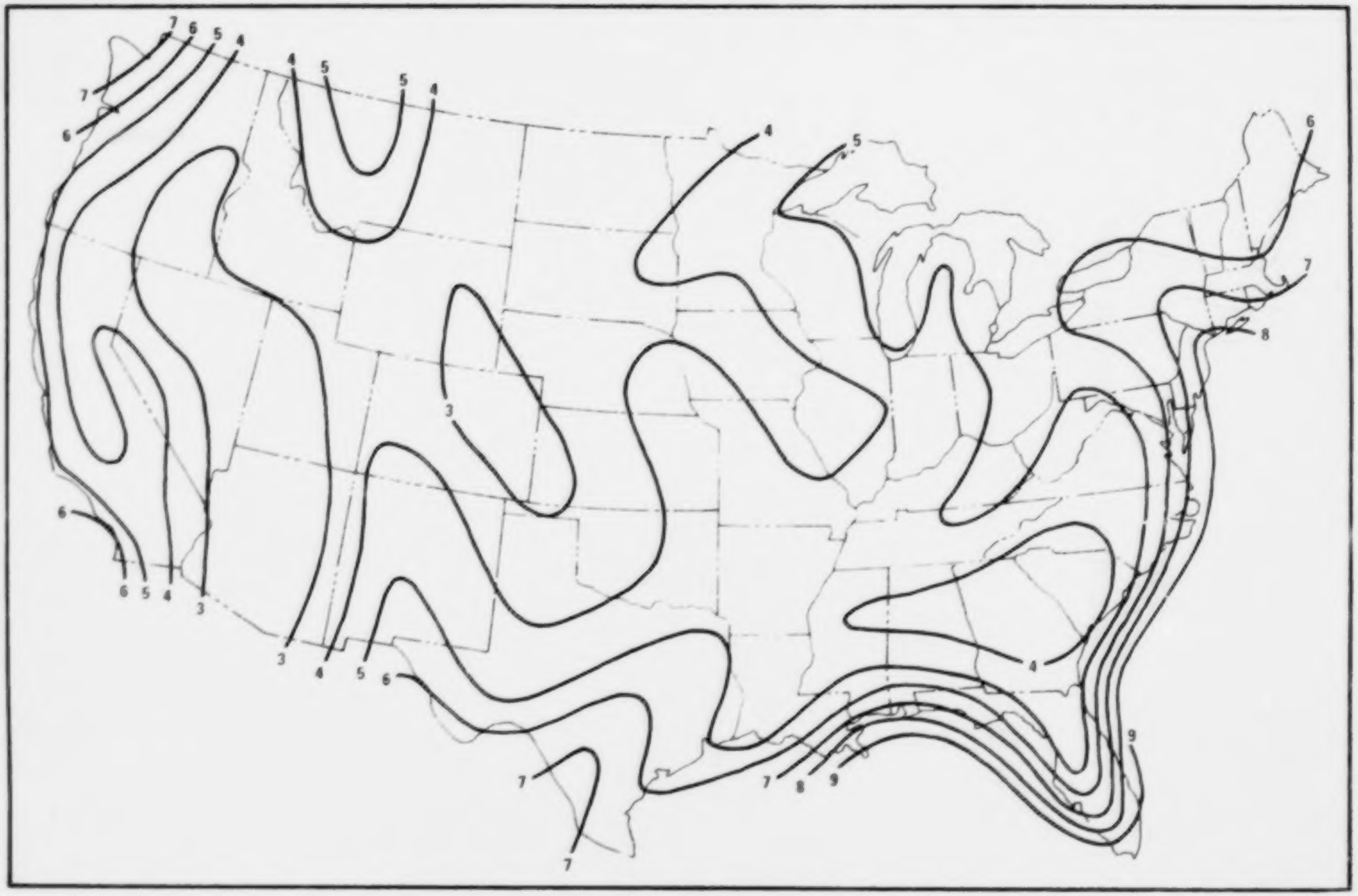
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Fig. 119. Isopleths of Mean Annual Morning Mixing Heights (10^2 meters)

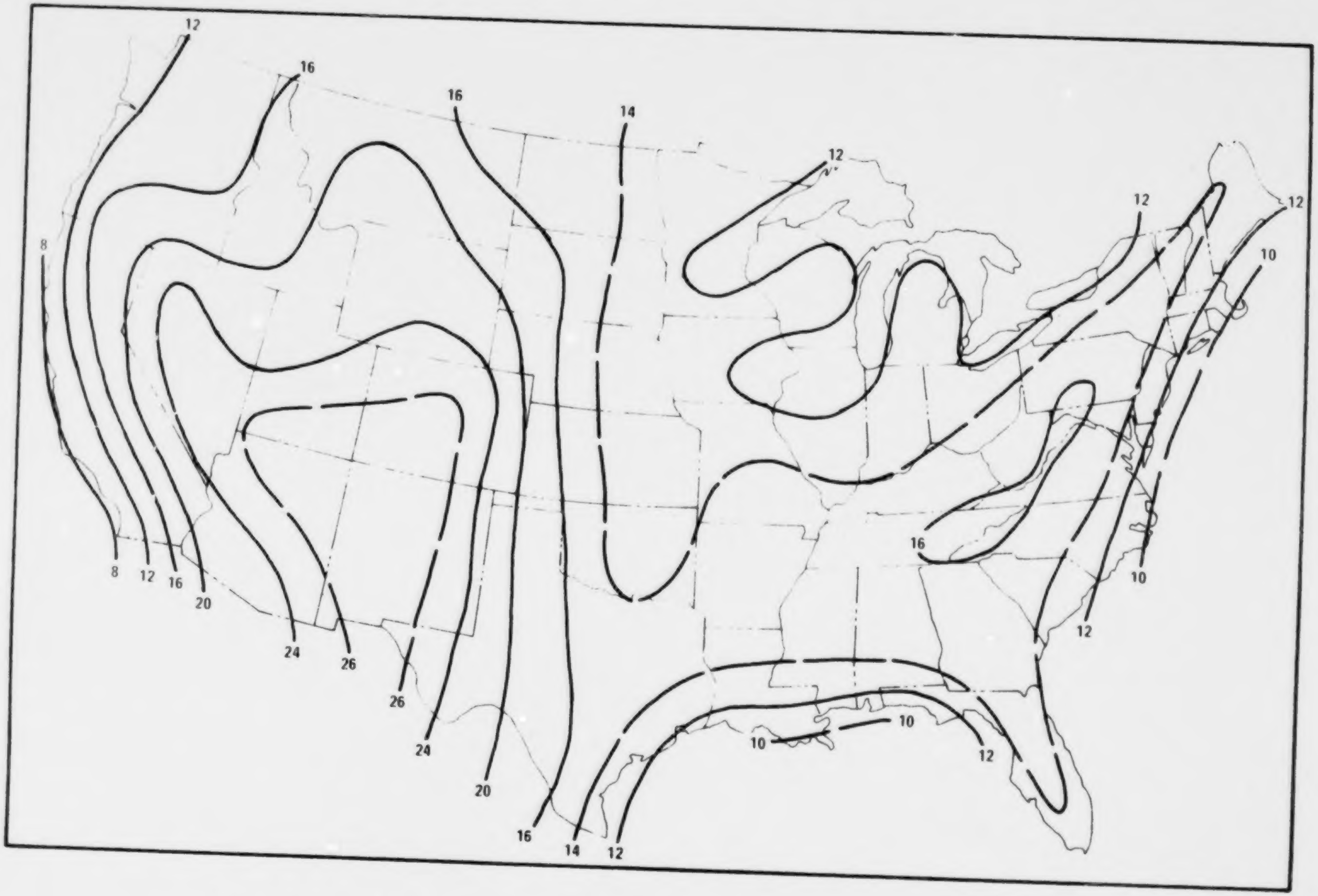
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Fig. 120. Isopleths of Mean Annual Afternoon Mixing Heights (10^2 meters)

APPENDIX E: UTM GRID JUNCTIONS

The data on the location of sources in the NEDS emission inventory are given in UTM coordinates. Monitoring station data usually give the UTM location of the station. Thus, using the UTM system can simplify gridding and locating these points.

As noted in Steps 1 and 2, UTM grid junctions occur every 6° of longitude. In the United States and its territories, the junctions are located at these longitudes: in the contiguous 48 states, at West 60°, 66°, 72°, 78°, 84°, 90°, 96°, 102°, 108°, 114°, 120°, and 126°; in Alaska and Hawaii at West 132°, 138°, 144°, 150°, 156°, 162°, 168°, 174°, 180°, and East 174°; and in the U.S. territories, East 126°, 132°, 138°, 144°, 150°, 156°, 162°, 168°, and other coordinates mentioned previously. See Fig. 121.

The junctions are places where two UTM grid zones meet. A UTM grid zone is a 6° wide strip of the earth running from the equator to the poles. The northing values are numbered from south to north starting at zero at the equator. The central meridian of each zone is given an easting value of 500,000 meters. From the zone's central meridian westward the easting values decrease, and eastward they increase. The purpose of the 6° strips is simple; since UTM is a Cartesian coordinate system, it consists of perfectly straight parallel and perpendicular lines. As one tries to transfer the features of the round earth onto flat paper, some deformation inevitably takes place. By taking 6° segments of the earth's surface, this deformation can be lessened.

But, the increase in accuracy created by the 6° wide zones creates the grid junction problem: on either side of the junction line a different baseline is used -- thus UTM lines on one side of the junction are not parallel to those on the other side.

The dispersion model requires the UTM coordinates to be assigned relative to a single axis. This guidebook has coined the term "normalization" to describe the act of placing UTM coordinates on either side of a grid junction into terms of a single UTM zone Normalization must be performed for any region containing a grid junction. Regions without junctions may totally ignore all references to normalization.

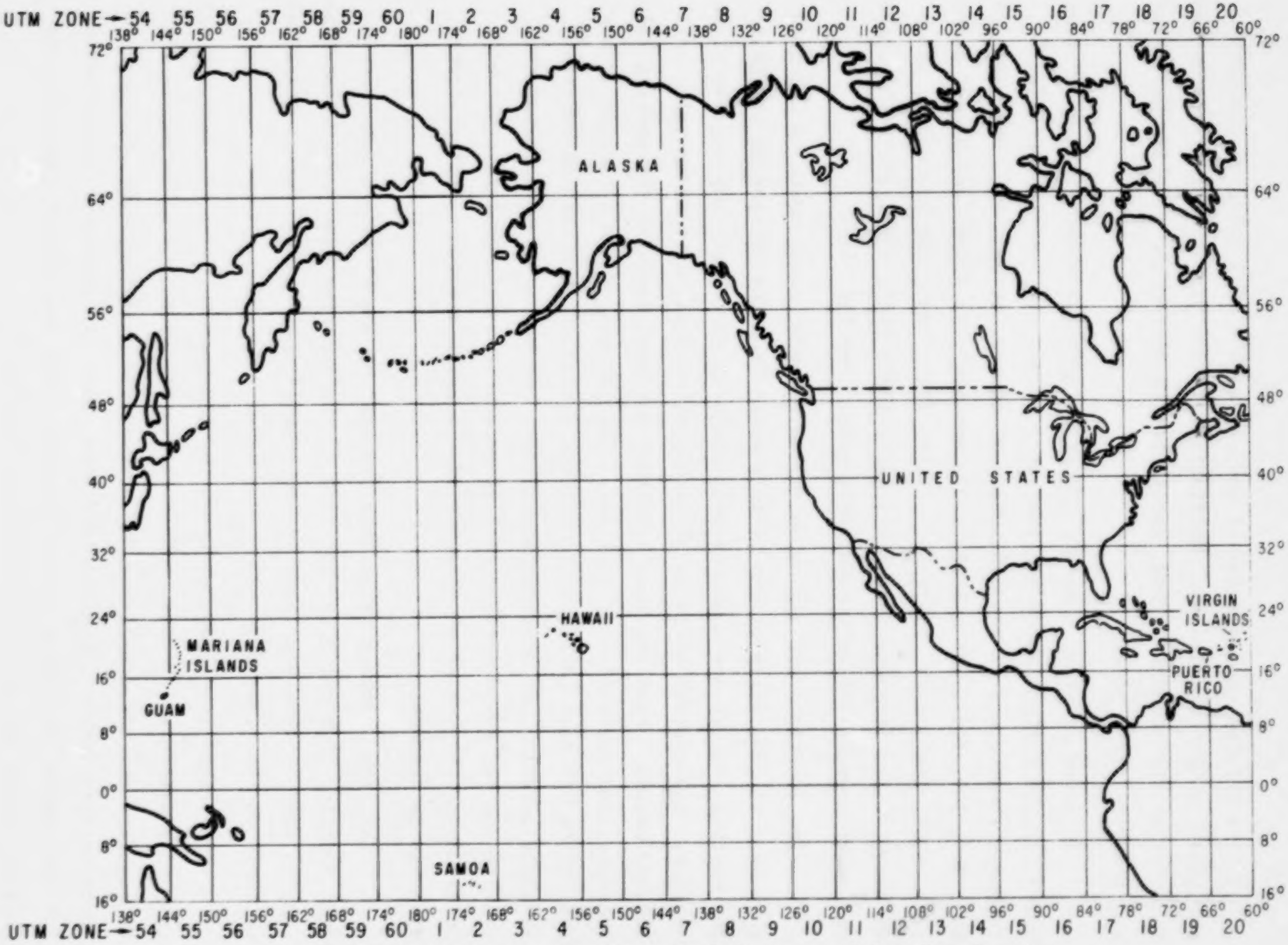

UTM ZONE→54 55 56 57 58 59 60 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
138° 144° 150° 156° 162° 168° 174° 180° 174° 168° 162° 156° 150° 144° 138° 132° 126° 120° 114° 108° 102° 96° 90° 84° 78° 72° 66° 60°
72°
64°
56°
48°
40°
32°
24°
16°
8°
0°
8°
16°
ALASKA
UNITED STATES
HAWAII
MARIANA ISLANDS
GUAM
SAMOA
VIRGIN ISLANDS
PUERTO RICO

Fig. 121. UTM Zone Numbering in the United States and Its Territories

For regions with grid junctions, normalization must be done for all UTM coordinates used in the EDZ methodology. This means the EDZ grid system, and the locations of EDZ receptors, monitoring stations, and pollution sources must be in normalized UTM coordinates. Both hand and machine (computer) normalization methods are described here. If computer resources are available, the machine methods will be easier to use. Cartographic methods should be used to plot the EDZ grid system. All of the mapping procedures are assumed to be performed on the general regional map produced in Step 1. All references to point normalization assume the point data, such as point source and monitoring station locations, have been collected.

Hand Normalization Methods

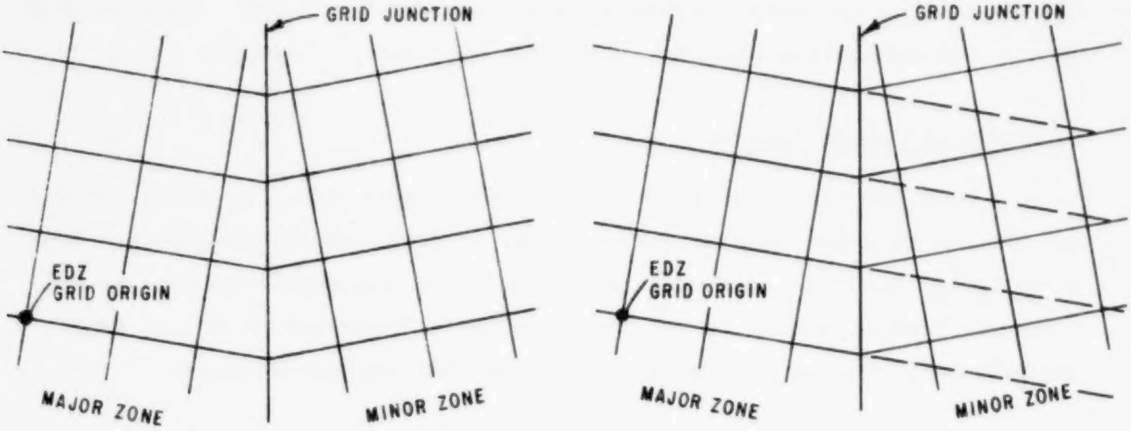
Hand methods involve no computer assistance and, therefore, require no special equipment beyond cartographic supplies and a calculator. Hand methods are somewhat less precise than machine calculations, but the difference is small enough to not create major differences in EDLs. Hand methods will tend to take more labor time than machine methods.

Cartographic Method. The cartographic method is probably the simplest method available for normalizing UTM coordinates, and should definitely be used for normalizing the EDZ grid system. First, determine which of the two UTM zones in your region will be the "major zone," or the zone where coordinates will not change. The decision should be based on items such as the location of point sources and monitoring stations. The zone with the fewest points to be changed should be the one to have its coordinates change. For simplicity, we will call this zone the "minor zone."

For this discussion, it is assumed that the zone covering the western points of the region is the major zone, while the eastern zone is the minor zone. Those with the opposite situation should have no trouble making the appropriate adjustments.

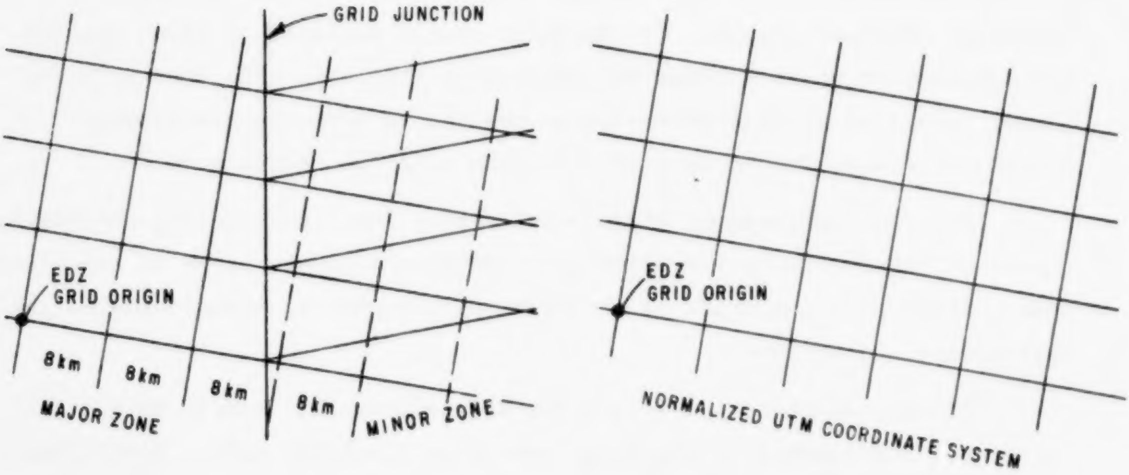
To cartographically produce the EDZ grid system, simply extend the horizontal UTM lines from the major zone into the minor zone. Place lines perpendicular to the extended lines at least once every multiple of 8 km from the EDZ grid origin. The northing values in the minor zone are now the same as those of the major zone. The easting values are determined by extending the coordinates of the major zone into the minor zone. (see Fig. 122). Aggregating or subdividing squares proceeds as stated in Step 2.

Point sources and monitoring sations will have their UTM coordinates given in terms of the UTM zone in which they are located. Therefore, the coordinates of points in the minor zone must be normalized. One problem with points is that the change from one zone to another represents a change in both easting and northing. For cartographically normalizing points, first perform


GRID JUNCTION
EDZ
GRID ORIGIN
MAJOR ZONE
MINOR ZONE
GRID JUNCTION
EDZ
GRID ORIGIN
MAJOR ZONE
MINOR ZONE

1. GRIDS BEFORE NORMALIZING

2. EXTEND HORIZONTAL (NORTHING) LINES INTO MINOR ZONE


GRID JUNCTION
EDZ
GRID ORIGIN
8km
8km
8km
8km
MAJOR ZONE
MINOR ZONE
EDZ
GRID ORIGIN
NORMALIZED UTM COORDINATE SYSTEM

3. PLACE PERPENDICULAR (EASTING) LINES INTO MINOR ZONE

4. ELIMINATE MINOR UTM SYSTEM AND GRID JUNCTION

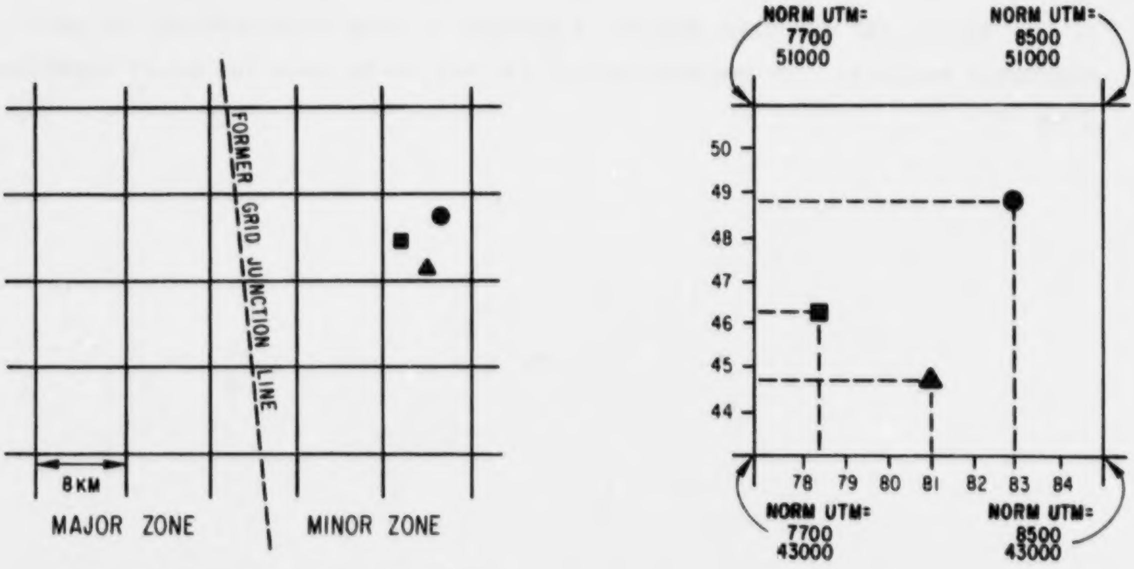
Fig. 122. Producing a Normalized Grid System

the grid normalizing in the minor zone. Then, subdivide the 8 x 8 km grid squares in the minor zone as shown in Fig. 123. From here, estimation is done by reading the coordinates of each point off the map. A ruler should be used to improve the accuracy of the estimate.

Mathematical Methods. The U.S. Army, which uses the UTM system to precisely locate targets, has developed a number of mathematical methods for normalizing coordinates. Since these methods are fairly complex and involve the use of a lengthy set of "transformation tables," if you wish to use them request the following publications from Headquarters, Department of the Army, Washington, D.C.: U.S. Army Technical Manual TM5-241-2, *Universal Transverse Mercator Grid Zone to Zone Transformation Tables* (1957); and U.S. Army Technical Manual TM5-241-8, *Universal Transverse Mercator Grid* (April 1973).

Machine Normalization Method

The machine normalization method uses a computer program to perform the calculations. The UTM coordinates for all points in the minor zone are required in order to use the computer program. The program, U.S. Geological


FORMER GRID JUNCTION LINE
8 KM
MAJOR ZONE
MINOR ZONE
NORM UTM= 7700 51000
NORM UTM= 8500 51000
50
49
48
47
46
45
44
78
79
80
81
82
83
84
NORM UTM= 7700 43000
NORM UTM= 8500 43000

ONCE THE NORMALIZED GRID HAS BEEN COMPLETED, POINT NORMALIZATION MAY BE PERFORMED BY PLOTTING THE POINTS AND INTERPOLATING WITHIN THE SQUARES

■ IS AT NORM 7,845, 46,300
▲ IS AT NORM 8,100, 44,750
● IS AT NORM 8,300, 48,800

Fig. 123. Cartographic Method for Normalizing Points

Survey No. J-380, is available on cards from: Chief, Branch of Photogrammetry, National Center, Stop #510, 12201 Sunrise Valley Drive, Reston, VA 22092, or phone: 703-860-6271. An experienced programmer should be available to compile and execute the program. The program is designed for a Fortran G compiler and an equivalent computer region of 130K.

The data card for each point to be normalized has the following format:

Columns	Type	Contents
1 - 33	blank	---
34 - 44	F11.3	Northing of a point in the minor zone
45	blank	---
46 - 55	F10.3	Easting of the same point in the minor zone
56	blank	---
57 - 58	I2	Number of major UTM zone
59 - 62	blank	---
63 - 64	I2	Number of minor UTM zone
65 - 80	blank	---

The map in Fig. 121 should be used to identify the zone numbers required in Columns 57 - 58 and 63 - 64.

Again, the EDZ grid system is assumed to have been produced by cartographic methods. The machine method is only to be used for point normalization.

APPENDIX F: GRID SYSTEMS OTHER THAN UTM

Appendix F explains what to do if the locations of monitoring stations or point sources are in state plane coordinates, latitude and longitude, or other coordinate systems. All location data must be in UTM coordinates for use in the dispersion modeling described in Steps 14 - 16. Cartographic, mathematical, and machine methods are available for transforming non-UTM to UTM coordinates; each method is described below. The location data, in non-UTM coordinates, must of course be secured before the required transformation to UTM coordinates can begin.

Cartographic Method

The cartographic method is identical to the one described in Appendix E and will not be repeated here (plot the UTM system over the other system and change the coordinates to UTM). Without a computer, this is unquestionably the easiest way of performing the transformation.

Mathematical Method

This method is fairly complex and is best described by U.S. Army Publication TM 5-241-8, *Universal Transverse Mercator Grid* (April 1973). It is available from Headquarters, Department of the Army, Washington, D.C.

Machine Method

The machine method involves a packaged computer program that converts geographic coordinates to UTM coordinates. This means that state plane or other coordinates must be converted to geographic coordinates before they can be transformed to UTM. A conversion for state coordinates to geographic (or even to UTM) may be available from the state agency in charge of mapping. If it cannot provide conversions, then the points to be converted must be mapped and geographic coordinates estimated. The geographic coordinates, expressed in degrees, minutes, and seconds, are input into U.S. Geological Survey Program No. J-380, which is available from: Chief, Branch of Photogrammetry, National Center, Stop #510, 12201 Sunrise Valley Drive, Reston, VA 22092, or phone 703-860-6271. An experienced programmer should be available to compile and execute the program. The program is designed for a Fortran IV G compiler and an equivalent computer region of 130K.

The data card for each location for which coordinate conversion is required has the following format:

Columns	Type	Contents
1 - 4	A4	four digit identifying number
5	A1	blank or minus sign
6 - 7	I2	degrees latitude
8	blank	---
9 - 10	I2	minutes latitude
11	blank	---
12 - 17	F 6.3	seconds latitude
18	A1	blank or minus sign
19 - 21	I3	degrees longitude
22	blank	---
23 - 24	I2	minutes longitude
25	blank	---
26 - 31	F 6.3	seconds longitude
32 - 55	blank	
56 - 58	I3	UTM zone # (for those areas with UTM grid junctions use only the zone to zone transformation option if desired. Otherwise leave blank. See Appendix E on UTM grid junctions.)
59 - 80	blank	---

APPENDIX G: DIFFERENCES BETWEEN THE CDMQC AND AQDM DISPERSION MODELS

There are a number of differences in the input requirements and grid structure of CDMQC and AQDM which you should be aware of if you plan to use AQDM. These differences are summarized below.

1. Source Contribution Output

CDMQC can provide source contribution output (culpability lists) at all receptors. You may suppress the source contribution listing at any receptor if desired.

AQDM can provide source contribution output at only five receptors per run. You may choose the five receptors; if you do not, the program chooses the five receptors with the largest total concentrations at ground level for each pollutant. When using AQDM for EDZ, then, multiple air quality runs must be made so that source contribution lists will be provided for all receptors. For example, for 50 receptors, 10 runs must be made. However, a programmer can modify AQDM to produce a single, large source contribution list.

2. Superimposed Area Sources

CDMQC does not allow superimposed area sources; that is, estimates of the air quality impact from light, medium, and heavy manufacturing districts of each area source must be made in three separate air quality runs.

AQDM, however, does allow superimposed area sources, so only one air quality run is needed.

3. Size of Area Source Grid Squares

CDMQC requires that the area source grid squares have sides whose lengths are integral multiples of a basic grid square.

AQDM has no restriction on the size of area source grid squares.

4. Receptor Point Locations

CDMQC allows up to 200 receptors to be used; they may be placed anywhere in the region.

AQDM allows up to 225 receptors to be specified; however, their locations must correspond to intersections in a grid pattern having equidistant horizontal and vertical spacing. In addition 12 non-grid receptors may be used in the region, for a total of 237 receptors.

5. Monitoring Stations

CDMQC requires that there be at least three but no more than 50 monitoring stations. Monitoring stations are considered to be receptors; the limit of 200 receptors includes monitoring stations. Pollutant concentration data and source contribution lists are provided for monitoring stations as for any other receptor.

AQDM uses monitoring stations for calibration only; they are not considered to be receptors. There must be at least three but no more than 100 monitoring stations per pollutant. If you wish to obtain concentration data or a source contribution at a monitoring station, a receptor must be placed there (a non-grid receptor unless the monitoring station location happens to coincide with a grid receptor).

6. Maximum Number of Point and Area Sources

CDMQC allows a maximum of 200 point sources and 2500 area sources.

AQDM allows a maximum of 1000 point and area sources combined.

7. Meteorological Data Requirements

CDMQC requires the following data:

- joint frequency function of wind direction, wind speed, and stability class, based on six stability classes (Class 4 is separated into classes for day and night)
- vertical dispersion functions (SZA) for the six stability classes in meters
- average afternoon mixing height in meters
- average nocturnal mixing height in meters
- average annual atmospheric temperature in degrees Centigrade.

AQDM requires the following data:

- joint frequency function of wind direction, wind speed, and stability class (same as that used for CDMQC with the exception that only five stability classes are used. There is no separation of Class 4 into day and night. To get the corresponding five-class function from the six-class function, add together the frequencies of Classes 4 and 5 - that becomes Class 4, and Class 6 becomes Class 5).
- average afternoon mixing height in meters
- average annual atmospheric temperature in degrees Kelvin
- average annual ambient pressure in millibars

8. Emission Inventory Data Requirements

Both CDMQC and AQDM require the following data for point and area sources:

- coordinates
- stack height in meters (actual stack height for point sources, estimated average effective height for area sources)
- stack gas exit velocity in meters/second (point sources only)
- stack diameter in meters (point sources only)

In addition, CDMQC requires:

- annual average emission rate in grams/second
- width of grid square (area sources only) in meters
- stack exhaust temperature in degrees Centigrade (point sources only)

In addition, AQDM requires:

- annual average emission rate in tons/day
- source area (area sources only) in square kilometers
- stack exhaust temperature in degrees Kelvin (point sources only)

9. Coordinate System

Both CDMQC and AQDM can use any coordinate system with non-negative coordinates; however, the UTM system is recommended for both.

10. Monitoring Station Data

Both CDMQC and AQDM require the measured annual arithmetic mean concentration of each pollutant at each monitoring station, in micrograms/cubic meter.

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APPENDIX H: THE USE OF LINEAR PROGRAMMING PACKAGES OTHER THAN MPSX IN EDZ

INTRODUCTION

Linear programming packages are programs marketed by computer hardware and software companies that are designed to solve linear programming problems. They are often sold as part of a mathematical programming package which may also include mixed integer and separable programming capabilities.

Most packages allow the user to write a control program in a Fortran-like language. The control program calls for procedures that perform linear programming and related functions. Less common are packages which have a single control card on which options are specified. The former gives the sophisticated user more flexibility in solving a problem; the latter is simpler for those unfamiliar with linear programming.

Basic procedures available in all packages include those to set up the problem work matrix, solve for the optimal feasible solution, modify an existing problem, output the solution and related information, and do sensitivity analyses. The control languages consist of arithmetic, logical, program flow control, and data movement statements.

Following are reviews of the systems requirements and suitability for EDZ of linear programming packages available from some of the major computer manufacturers. Table 30 summarizes the capabilities of these packages. Refer to package documentation and company contacts for more details.

Table 30. Comparison of Linear Programming Packages

System Feature	Linear Programming System[a]									
	NCR LPS - 16K	NCR LPS - 32K	CDC APEX-III	UNIVAC FMPS	IBM MPS	IBM MPSX	Burroughs TEMPO	Honeywell LP H	Honeywell MPS	Haverly Systems LP/360
Max.[b] No. Variables & Constraints	180 49	1,000 120	32,760 8,190	Limited by hardware	4,095 rows	16,383 rows	11,000 rows	500 rows	4,095 262,000	4,096 rows
Algorithm Used	Dual simplex	Dual simplex	Product form of inverse/revised simplex	Tomlin L-U update method	Product form of inverse/revised simplex			Product form of inverse/revised simplex		
Input Modes	Card, Paper Tape, Disk		Card, Magnetic Tape, Disk		Card, Magnetic Tape, Disk			Card, Magnetic Tape, Disk		
Independent Procedures	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control Program or Control Card	Card	Card	Card or Program	Program	Program	Program	Program	Program	Card or Program	Program
Matrix Element Range of Value	999,999 -99,999	999,999 -99,999	User Specified	10^{307} -10^{308}	± ∞	± ∞	± ∞	10^{10} -10^{9}	± ∞	10^{13} -10^{12}
Bounded Variable Feature	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Free Variables Allowed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Linear Combs. of Rows Acceptable as Input Data	No	No	Yes	No	Yes	Yes	No	No	Yes	No
Slack Variables Introduced by System or User	System	System	System	User or System	System	System	System	System	System	System
Save/Restart Option	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Input Data Printout	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Output Reports Selected by User	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Only with Reporter Generator
Product of (Optimal Variable Activity & Objective Function) Output[c]	Yes	Yes	No	No	No	No	No	No	No	No
Parametric Programming on Objective Function, RHS[d]	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

[a] All systems listed here have the following features: (1) problem editing independent of problem solution; (2) selection lists for vectors; (3) error, iteration, optimal solution, and dual solution reports; and (4) sensitivity analysis on objective function and RHS.

[b] Theoretical maximum problem sizes as stated by system supplier. However, the maximum problem size that can be solved depends on a number of factors, including matrix density (number of non-zero coefficients), whether the problem has ranges or bounds, the number of work regions and buffers allocated, and the amount of memory available. EDZ linear programming problems will have very dense matrices, perhaps limiting the maximum problem size.

[c] Including this product as output eliminates the need for a time-consuming set of calculations; namely that of multiplying ACTIVITIES × INPUT COST in Step 24B.

[d] IBM MPS, IBM MPSX, Burrough TEMPO, and Honeywell MPS have procedures which also do parametric programming on selected rows and columns.

TEMPO/BASIC (Burroughs Corp.)

Machine B 7700/B 6700 Systems

Address

Burroughs Corp.
Eastern Center
2450 Swedesford Rd.
Box CB7
Malvern, PA 19355

Business Management & Scientific Systems
Burroughs Corp.
Burroughs Place
Detroit, MI 48232

Reference Publication *Burroughs B 7700/B 6700 Systems TEMPO Mathematical Programming System User's Manual*, Publication #1073665.

System Requirements

The problem size TEMPO/BASIC can handle depends on the amount of memory and the disk storage space available. Theoretically, TEMPO can handle a problem up to 11,000 rows, but machine time would make this a practical impossibility. The designed maximum is in the range of 4000-5000 rows. The following table illustrates the relationship of problem size, memory, and storage space.

	rows x columns and No. of non-zero matrix elements			
Memory and Storage	100 x 200 100	1000 x 2000 8000	2000 x 5000 20,000	4000 x 10,000 40,000
Memory Required (words)[a]	16,000	32,000	40,000	50,000
Disk Storage Space (bytes)	0.2×10^6	1.5×10^6	3×10^6	6×10^6

[a] In Burroughs systems, a word is 48 bits.

TEMPO files, the devices they require, and their functions are listed below. Required for solving a simple LP problem are CARD, DISKIN, and an output device (such as the printer). Work files are generated by the procedures. For large problems you can assign specific disk space to the files.

File Name	Device	Function
BRANCH	disk	save and restart data
CARD	card, disk, tape	control language statements
CARDIN	card, disk, tape	revision data, selection lists, etc.
CARDOUT	punch	problem and basis data
DISKIN	card, disk, tape	problem data

File Name	Device	Function
DISKOUT	disk	problem and basis data
MACROLIB	disk	control language statements
OLDZPROF	disk	problem storage
TAPEIN	tape	problem and basis data
TAPEOUT	tape	problem and basis data
ZPROF	disk	problem storage
ZSOLF	disk	storage of solution data
OLDSOLF	disk	storage of solution data

Suitability for EDZ

The designed normal maximum problem size that TEMPO can solve should make it suitable for any EDZ problem (see Step 12 for a discussion of EDZ problem size). A bounded variable feature is available to set limits on the values that structural variables may take (necessary for Step 21).

APEX-III (Control Data Corp.)

Machine
CDC CYBER 70 Systems - Models 72, 73, 74, 76
CDC CYBER 170 Systems
CDC 6000 Series Systems
CDC 7600 Systems

Address
Control Data Corp.
CYBERNET Services
P.O. Box 0 HQW05G
Minneapolis, MN 55440

Reference Publication *APEX III Reference Manual*, Publication #76070000.

Comments

APEX III has two basic systems, one of which is an all-in-core system (APEX-III Base System 1) and one which has the capability of using disk or extended core storage as additional storage (APEX-III Out of Core System 1). The APEX-III Parametrics Option and Matrix Reduction Option are not part of the basic system and must be purchased separately.

Apex III allows you to write a control program to control the solution strategy of an LP problem, as do many other packages, but the user may alternatively solve a problem by submitting, instead of a control program, a single card on which desired program options are specified. Although you lose flexibility with this alternative, it is easier and quicker. The options that can be specified using the single card include type of output, type of starting basis, and whether the solution basis should be saved.

System Requirements

CDC uses a unit called field length as a measure of central memory requirement. Field length may be expressed in octal or decimal numbers. The minimum field length for APEX-III processing is 60000_8. Equations for estimating the amount of central memory required for a given problem are found in Appendix A of the reference manual. The maximum problem size that can be solved regardless of the amount of memory available is 8190 rows, 32,760 columns, 32,760 unique, non-zero elements, and 2045 non-zero elements in a column.

You may wish to compare memory requirements given in field length to its equivalent in IBM bytes. A method for estimating the number of bytes is to multiply the field length in decimal numbers by 10. For example,

$60000_8 = 24576_{10}$
$24576 \times 10 = 245{,}760$ bytes
$245{,}760 \div 1024 = 240$ K bytes

McDonnell Douglas ran models for comparative purposes using APEX III on a CDC 7600 and MPSX on an IBM 370. Results comparing CPU times were:

CPU Times (seconds)			
CDC 7600	IBM 370	Model	
13.5	67.1	easy	depending on density of inverse
67.1	158	medium	
50.1	115	difficult	

Files used by APEX-III are listed below with their default file names. You may change the file name if you want the data assigned elsewhere. The files may reside on tape or direct access devices.

File Name	Purpose
TAPE 1	contains problem data for input
TAPE 3	contains user-specified starting basis
TAPE 4	contains solution basis
TAPE 5	contains information saved for a later restart
TAPE 12	contains solution data
TAPE 13	an output file containing problem in input format
TAPE 14	contains revision data
TAPE 15	used by REDUCE option
TAPE 16	used by REDUCE option
TAPE 17	used by REDUCE option

Suitability for EDZ

The theoretical maximum problem size that APEX-III can handle should make it suitable for any EDZ application (see Step 12 for a discussion of EDZ problem size). A bounded variable feature is available to set limits on the values that structural variables may take (necessary for Step 21).

LP 360/370 LINEAR PROGRAMMING SYSTEM (Haverly Systems, Inc.)

Machine IBM System/360 or System/370

Address Haverly Systems Inc.
78 Broadway
Denville, NJ 07384

Reference Publication *LP 360/370 Linear Programming System User and Operating Manual*

Comments

Haverly Systems, Inc., is an independent software company that provides five versions of the LP 360/370 Linear Programming System corresponding to various sizes and operating systems for the 360/370 machines. The version discussed here will be OS LP/360, which is designed for medium to large computers of the 360/370 series in an operating system environment.

A difference between OS LP/360 and MPSX is that OS LP/360's optimizer is less expensive to run than MPSX's; however OS LP/360 can handle problems of up to only 4096 rows. Another difference is that OS LP/360 does not have provisions in its input data format for bounded variables and ranged constraints, as does MPSX. Thus, bounds on variables must be expressed as separate constraints, and constraints which have both upper and lower bounds must be entered as two separate constraints.

System Requirements

OS LP/360 requires a minimum core of 64K. The problem size it can handle is dependent on the amount of core available as shown in the following table.

Core Size	Maximum # of Rows
64 K	920
128 K	2515
256 K	4095

The LP system is distributed on tape but should be transferred to a direct access device such as a 3330 disk pack. See Appendix M of the reference for details.

System files required by OS LP/360 are:

HSILP 360 - the file containing the agendum programs
PRINTFILE - printer or other output device
CARDFILE - card reader or other input device

If the problem is small enough, it can be run entirely in core. If not, the agenda (procedures) INPUT and OPTIMIZE will require the following files, which may reside on disk or tape:

INPUT 1. LPMATRIX - contains binary matrix records
2. SCRATCH - contains negative slack variables

OPTIMIZE 1. LPMATRIX - contains binary matrix records
2. SCRATCH - contains eta records
3. SOLUTION - scratch tape

Other agenda (procedures) require other files that may be assigned by the user. For more details, see page B-3 of the reference. For information on calculating storage requirements for these files, see page P-18. A general rule is to allocate, for any given file, a minimum of 50 cylinders on a 2311 disk, or 30 cylinders on a 2314 disk.

Suitability for EDZ

OS LP/360 does not have bounded variable or constraint range features. Therefore the bounds calculated in Step 21 must be incorporated into the LP model as two constraints for each variable - one constraint for the upper limit and one for the lower limit. In this case the number of rows (constraints) in an EDZ problem will be the number of receptors plus two times the number of structural variables. OS LP/360 can handle a maximum problem size of 4096 rows, however, so it should be able to handle any EDZ problems (see Step 12 for a discussion of EDZ problem size).

SERIES 200 LINEAR PROGRAMMING SYSTEM H (LP H) (Honeywell)

Machine Series 200 Processors

Address Honeywell Information Systems
Management Sciences
600 Walnut Street
Wellesley Hills, MA 02181

Reference Publication *Honeywell Series 200 Linear Programming System H*, Publication #BB72, Rev. 0.

System Requirements

The minimum equipment configuration required to run LP H is:

- A series 200 processor with minimum memory size of 32,768 characters (32K);
- Five magnetic tape units; and
- A card reader, printer, and card punch

Optional equipment for problem sizes larger than the minimum are (1) additional memory up to a maximum of 131,072 characters, and (2) two magnetic tape units.

Problem size is dependent on the amount of memory available, as shown below:

Core Size (memory)	Max. Problem Size (# rows)
32K	70
40K	125
48K	250
65K	500

Input data may reside on cards or as card images on a magnetic tape. Input data use two types of cards: announce, or indicator cards, which tell which type of data is to follow, and problem data cards, which contain the actual values.

Suitability for EDZ

LP H does not have bounded variable or constraint range features. Therefore the bounds calculated in Step 21 must be incorporated into the LP model as two constraints - one constraint for the upper limit and one for the lower limit. In this case the number of rows (constraints) in an EDZ problem will be the number of receptors plus two times the number of structural variables. Because the maximum problem size for LP H is in the area of only 500 rows, this system is only useful for small EDZ problems (see Step 12 for a discussion of EDZ problem size).

HONEYWELL MATHEMATICAL PROGRAMMING SYSTEM (MPS) (Honeywell)

Machine Series 6000 Processors

Address
Honeywell Information Systems
Management Sciences
60 Walnut Street
Wellesley Hills, MA 02181

Reference Publications *Series 6000 Mathematical Programming System Implementation Guide*, Publication #DC55, Rev. 0.

Series 6000 LP6000 System Agenda Control Language, Publication #BQ19.

LP6000 System Input File Preparation, Publication #BQ01.

Comments

MPS evolved from and is fully compatible with Honeywell's Series 6000 Linear Programming System. It differs in that it has a remote processing capability, can call user-written programs, and has facilities for converting IBM 360/370 LP models and Honeywell Series 200 models into a format acceptable to MPS.

System Requirements

MPS requires the following minimum equipment configuration:

- Series 6000 central system and consol
- one magnetic tape unit (unless MPS resides on disk or drum)
- disk or drum storage
- a card reader, printer, and card punch

The following optimal core requirements are given for various problem sizes.

Elements in Problem*	Core Requirement
10-7500	36K-48K
7500-35,000	48K-56K
35,000-200,000	56K-66K
>200,000	66K+

*Elements include rows, columns, matrix coefficients, and RHS elements.

Three logical devices are required by MPS for temporary storage of the eta file, alpha file, work file, and possibly the problem file. If the problem file is large, you may wish to assign bulk storage (disk or drum) space for it. For details on the amount of storage space required, see Appendix C of the first reference.

Suitability for EDZ

Honeywell's MPS can handle maximum problem sizes of over 200,000 elements (roughly corresponding to a problem size of 200 rows by 1000 columns. It should be suitable for most EDZ problems (see Step 12 for a discussion of EDZ problem size).

A bounded variable feature is available to set limits on the values structural variables may take (necessary for Step 21).

MATHEMATICAL PROGRAMMING SYSTEM/360 (MPS/360) (IBM Corp.)

Machine System/360

Address Local IBM data processing sales office or

International Business Machines Corp.
Data Processing Division
1133 Westchester Avenue
White Plains, NY 10604

Reference Publications *MPS/360 Version 2, Linear and Separable Programming User's Manual*, Publication #GH20-0476-2.

MPS/360 Version 2, Control Language User's Manual, Publication #GH20-0290-3

Comments

MPS/360 is obsolete and has been replaced by IBM's MPSX, which is more efficient and has greater capabilities. It is included here, however, because as some installations may still use it.

System Requirements

MPS/360 requires an IBM System/360 with a minimum memory region of 64K bytes (65,536 bytes). The problem size it can handle is dependent on the amount of region available as shown in the following table.

	data bytes		
rows	82,500	475,000	992,000
designed norm	200-700	1600-3500	≥3500
maximum	2120	4095	4095

The maximum problem size assumes a minimum number of buffers and work regions and no ranges or bounds in the problem.

System files and their associated devices required by MPS are:

- SYSMLCP: Contains machine language representation of the control program. Must be a direct access device.
- SYSPRINT: Contains output of program. May be a line printer or a magnetic tape unit.
- SYSIN: Contains input stream. Can be a card reader or magnetic tape.

Internal files used for temporary and permanent storage of data are:

- PROBFILE: Contains problem in input format
- MATRIX: Contains work matrix
- ETA: Contains the product form of the inverse
- SCRATCH 1: Used for utility functions
- SCRATCH 2: Used for utility functions
- MPSCRAT: Work region for post-optimal procedures

These files may be on direct access devices or tape. Space allocation for these files is dependent on the problem size, configuration, and density. See Figure 81 of the first reference for a method of calculating this.

MPS/360 supports the 2311, 2314, 2301, 2302, and 2303 direct access devices, and the 2400 series magnetic tape units.

Suitability for EDZ

MPS can handle a maximum problem size of 4095 rows, but that is for a problem with no bounds or ranges. The designed normal maximum is about 3500 rows, which makes it large enough for any EDZ problem (see Step 12 for a discussion of EDZ problem size).

A bounded variable feature is available to set limits on the values structural variables may take (necessary for Step 21).

MATHEMATICAL PROGRAMMING SYSTEM EXTENDED (MPSX) (IBM Corp.)

Machine System/360 or System/370

Address Local IBM data processing sales office or

International Business Machines Corp.
Data Processing Division
1133 Westchester Avenue
White Plains, NY 10604

Reference Publications *Mathematical Programming System - Extended (MPSX), and Generalized Upper Bounding (GUB) Program Description*, Publication SH20-0968-1.

MPSX Control Language User's Manual, Publication SH20-9932-0.

Comments

MPSX differs from MPS/360 in performance improvement and added features. The coding of the PRIMAL and INVERT procedures has been changed, the routines for obtaining a good starting basis have been improved, and new procedures have been introduced which check for possible size reduction and provide different optimization mechanics. New features of MPSX include increased processing capacity (to 6,000 rows), simplified output filing, use of labeled tapes, new communication region cells, and new procedures.

System Requirements

MPSX requires an IBM System/360 or System/370 with a minimum region of 128K. The problem size that MPSX can handle is dependent on the amount of region available as shown in the following table.

	data bytes		
rows	100,000	500,000	800,000
designed norm	200-800	2500-5000	4000-6000
maximum	2617	13,729	16,383

The maximum problem size assumes a minimum number of buffers and work regions and a problem with no ranges or bounds.

A 2400 or 3400 series magnetic tape unit is required for installation because the program is released on tape. Direct access storage requires approximately eight cylinders on a 2314 device. MPSX also supports the 2311, 2319, 2301, 2302, 2303, 2305, and 3330 direct access devices.

Files required by MPSX are:

- SYSIN: System input file.
- SYSPRINT: System output file.
- SYSMLCP: Contains machine language representation of the control program. Must be a direct access device.
- MATRIX 1: Contains the work matrix
- ETA 1: Contains the product form of the inverse.
- SCRATCH 1: Used for temporary data storage
- SCRATCH 2: Used for temporary data storage
- PROBFILE: Contains problem in input format

Optional MPSX files include:

- OLDPFILE: Contain problems in input format.
- MATRIX 2-4: Up to four devices can be used to store the work matrix of the model.
- ETA 2-4: Up to four devices can be used to store the product form of the inverse.
- MPSCRAT: Work region for post-optimal procedures. Must be a direct access device.

Suitability for EDZ

MPSX can handle a maximum problem size of 16,383 rows, but that is for a problem with no bounds or ranges. The designed normal maximum is about 6000 rows, making it large enough for any EDZ problem (see Step 12 for a discussion of EDZ problem size).

A bounded variable feature is available to set limits on the values structural variables may take (necessary for Step 21).

NCR LINEAR PROGRAMMING SYSTEM (LPS) (National Cash Register Co.)

Machine NCR Century

Address Local NCR Branch or

National Cash Register Co.
Management Sciences
741 Marketing Building
5225 Springboro Pike
West Carrollton, OH 45449

Reference Publication *Linear Programming*

Comments

NCR LPS can run with a memory size of 16K or 32K. The difference is that with 32K memory a restart facility is available and larger problems can be handled. This system is easy to run because there is no control language with many procedures and statements; control over the program is provided by a single card on which the user specifies the options desired. Although this is good for the novice and those running simple programs, the more sophisticated user may note the lack of flexibility.

System Requirements

NCR LPS can run with a memory requirement of 16K bytes or 32K bytes (K = 1024). Storage requirements for each case are given by the following table:

Memory Requirement	Pack 1	Pack 2
16K	2300 sectors*	--
32K	2400	2400
32K w/output filed on disk	3650	2400

*A sector is a division of a disk pack: for example, a 655 pack contains 8900 sectors and 512 characters/sector.

The largest problem size that can be solved is:

bytes	#row	#columns
16K	49	180
32K	120	1000

Input data can be on cards, paper tape, or disk; output is to the printer or to disk.

Suitability for EDZ

NCR LPS used with an available memory size of 16 K would be suitable for only small EDZ problems. Run with an available memory size of 32K, LPS is suitable for larger EDZ problems (see Step 12 for a discussion of EDZ problem size).

NCR LPS has a provision for specifying bounds on the values structural variables may take (necessary for Step 21).

NCR includes as part of its optimal solution report output the product of the optimal variable activity and the objective coefficient. This eliminates a time-consuming set of calculations - that of multiplying ACTIVITIES × INPUT COST in Step 24B.

FUNCTIONAL MATHEMATICAL PROGRAMMING SYSTEM (FMPS) (Sperry Univac)

Machine 1100 Series

Address
Chicago Commercial Branch
Sperry Univac
Marina City
300 North State Street
Chicago, IL 60610

Reference Publication *Sperry Univac 1100 Series FMPS Programmer Reference*, Publication #UP-8198.

System Requirements

The problem size FMPS can handle is not limited by the program, but by hardware capability. Some examples of the memory size required for a given problem size are:

memory size in words	30K	43K	63K
number of rows	<500	<1200	<3400

A word = 36 bits = 6 bytes.

Internal files required by FMPS are:

• MATRIX:	Contains the internal representation of the matrix.
• INVERSE:	Contains the product form of the inverse.
• UTIL 1:	Scratch file.
• UTIL 2:	Scratch file.
• PREPDEVI:	Contains compiler output of the control language program.

The first four files may be assigned by the program or the user; the fifth may not be assigned by the user. These files are all assigned to mass storage, which can be either disk or drum. Optional files are:

• RESTART:	Used to save problem files and status for a later resumption of the run.
• 'ANYNAME':	User-defined files for communication between FMPS and user programs.

These files are assigned by the user to any sequentially accessed device.

The mass storage space requirements for a given problem may range from 2 to 10 positions, where one position = 64 tracks and one track = 1792 words. For example, a problem of 4000 rows by 4000 columns would need approximately 6 positions. For more detail on estimating mass storage requirements, see Section 2.5.3 in the reference.

Suitability for EDZ

Because problem size limitations are imposed only by hardware requirements and not by the linear programming system itself, FMPS should be suitable for any EDZ problem provided there is enough memory available (see Step 12 for a discussion of EDZ problem size).

A bounded variable feature is available to set limits on the values that structural variables may take (necessary for Step 21).

APPENDIX I: SPECIAL REGIONAL PROBLEMS

[or, what to do if the region has • less than 3 monitoring stations • more than 50 monitoring stations • more than 200 point sources • more than 200 receptor points • more than 200 point sources and more than 200 receptors • an area less than 350 square kilometers • more than 350 area sources (grid squares)]

Less Than 3 Monitoring Stations

CDMQC's calibration run will not work with fewer than three monitoring stations. In this situation, the background concentration must be estimated through methods which are beyond the scope of the guidebook. The slope of the regression line should be taken as 45°, i.e. $b = 1$, unless the available monitoring data show that it should be otherwise.

More Than 50 Monitoring Stations

The CDMQC calibration run allows for a maximum of 50 monitoring sites to be used in calculating calibration coefficients. If there are more than 50 sites in your region, select a sample of 50 sites to be used in the calibration run. The rest of the monitoring stations may be ignored. Criteria for selection of one station over another may be random or based on quality of the data or the location relative to other monitoring sites.

More Than 200 Point Sources

For large regions, more than 200 point sources will be found in the emission inventory. This can be a problem because under no circumstances may more than 200 point sources be input into any one run of CDMQC.*

The solution to this problem in the right-hand-side run is to run CDMQC more than once and combine the results of each run by hand or by computer if there is a programmer available. This could be done through combining culpability lists for each receptor. In this way, the contribution from each exempt source will be noted and the pollutant concentrations at each receptor kept separate.

---

*Unless an experienced programmer on your staff increases the dimensions of the CDMQC program to take a greater number of sources.

More than 200 point sources in the calibration run also poses problems. The calibration run provides a regression line showing the correlation between pollutant concentrations calculated by the model and concentrations observed at monitoring stations (Fig. 124 illustrates a regression line for a region with six monitoring stations.*) Since this is a simple straight-line regression, in those areas with more than 200 point sources, the regression may be done by using a statistical computer package or a pocket calculator with regression analysis capability.

The steps to be followed for the more-than-200-point-sources calibration run are:

1. Collect monitoring station and emission inventory data.
2. Keypunch these data and place the cards into the deck according to the directions in Step 9.
3. Change the following card:

   The Type 2 Card for the calibration run should be removed from the deck and the Type 2 Card for the air quality and right-hand-side runs substituted. This change is needed to avoid excess run time. Since calibration is not desired, this change tells the computer not to bother.

4. Run CDMQC as many times as is required to include all sources. (So, for 201 to 400 sources, the model is run twice, for 401 to 600 sources, the model is run three times, etc.)
5. Find the total pollutant concentration calculated at each monitoring site by summing the contributions made to each monitoring site from the sources included in each run.
6. Use the monitoring station data and the calculated concentrations to perform the regression analysis. The slope and intercept values you obtain are used in Step 20.

More Than 200 Receptors

Since you create receptor points, the decision on how many are sufficient to cover the region is totally your decision. If more than 200 are selected, CDMQC will have to be run more than once for the light, medium, and heavy manufacturing air quality runs, and the right-hand-side runs, with the receptors changing from run to run. An alternative solution is to have an experienced programmer change the dimensions of the CDMQC program.

---

*This graph is not CDMQC output; it is provided to illustrate the concept of a regression line. CDMQC provides values for the slope and intercept of a regression line.

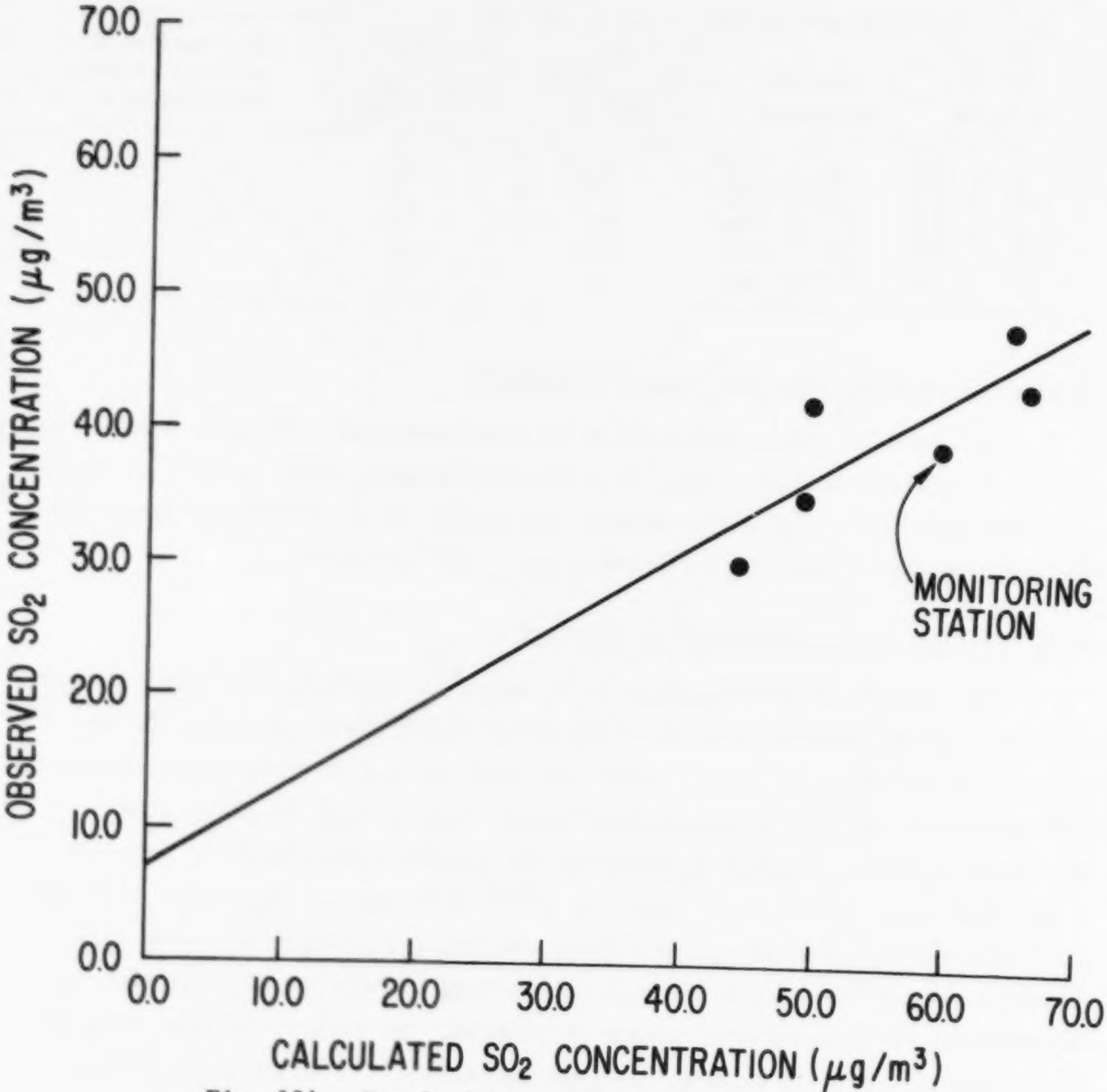


Fig. 124. Sample Sulfur Dioxide Regression Line

More Than 200 Point Sources and More Than 200 Receptors

This can be a problem only in the right-hand-side run. Regions exempting many point sources may exceed the 200 limit. In the > 200 sources, > 200 receptors case, CDMQC must be run twice for every multiple of 200 plus twice for any fraction over 200. Results from all the runs are combined to give the overall picture as shown below. An alternative solution is to have an experienced programmer change the dimensions of the CDMQC program.

No. of Point Sources	No. of Receptors	No. of Runs Required	No. Runs with Point Source Card Changes	No. Runs with Receptor Point Card Changes
up to 200	up to 200	1	0	0
201 to 400	up to 200	2	1	0
up to 200	201 to 400	2	0	1
201 - 400	201 to 400	4	1	1
401 - 600	401 to 600	6	2	2

Regional Area Less Than 350 Square Kilometers

The rule of thumb stated in Step 2 suggests that 350 grid squares be used. In regions smaller than 350 square kilometers, this is neither necessary nor desirable. In such regions, the entire area could be covered with one kilometer grid squares to provide increased accuracy.

More Than 350 Area Sources (Grid Squares)

The number of grid squares in a region is optional, but grids larger than 16 x 16 kilometers are not recommended since their use tends to decrease the model's accuracy. CDMQC can take up to 2500 grid-square-defined area sources; therefore, the authors would like to make it clear that 350 is an arbitrary number believed to be a manageable number of squares. A few more than 350 will not make any major difference. Many more than 350 will make the problem very, very large and cause a problem with the time required to run the linear programming package. Use your own judgment in deciding on the appropriate number of squares. Be sure to re-read Step 17 (on construction of the linear program matrix) before choosing more than 350 squares.

APPENDIX J: REPRODUCIBLE WORKSHEET FORMS

WORKSHEET I (FOR STEP 2) FILLED OUT BY: ____________ DATE ______ PG ___
LIST OF SOUTHWEST CORNERS OF EDZ GRID SQUARES OF ___

EDZ GRID SQUARE NUMBER	NORMALIZED NORTHING IN km	NORMALIZED EASTING IN km

WORKSHEET 2 (FOR STEP 2) FILLED OUT BY: ____________________ DATE ________ PG ___
PERCENTAGE AND AREA OF EDZ SOURCES OF ___

EDZ GRID SQUARE NUMBER	AREA OF GRID SQUARE (km^2)	SIMPLIFIED LAND USE CLASS							
		A		M1		M2		M3	
		%	AREA: % x GRID SQUARE AREA (km^2)	%	AREA: % x GRID SQUARE AREA (km^2)	%	AREA: % x GRID SQUARE AREA (km^2)	%	AREA: % x GRID SQUARE AREA (km^2)

WORKSHEET 3 (FOR STEP 3) FILLED OUT BY: ____________ DATE ________ PG ___
LIST OF RECEPTOR LOCATIONS OF ___

RECEPTOR NUMBER	EASTING IN km	NORTHING IN km	NOTES ON THE REASON FOR SELECTING THIS LOCATION FOR A RECEPTOR (CENTER, SENSITIVE, POLITICAL JURISDICTION, MONITORING SITE, ETC.)

WORKSHEET 4 (FOR STEP 4) FILLED OUT BY: ______________ DATE ________ PG 1
METEOROLOGICAL DATA OF 1

THIS WORKSHEET SHOWS THE EXACT FORMAT THAT THE METEOROLOGICAL DATA MUST BE IN FOR INPUT TO CDM-QC.

1. MEAN ANNUAL ATMOSPHERIC TEMPERATURE

FOR EXAMPLE, |0|0|1|3|8|3| WOULD BE READ BY CDM-QC AS 13.83° CELSIUS.

PLEASE PLACE YOUR FIGURE HERE; USE NO DECIMAL POINT. ENTER THIS NUMBER IN COLUMNS 61-66 OF CARD 4, FOR ALL FIVE CDM-QC RUNS. SEE STEP 9.

|0|0| | | | |

2. MEAN ANNUAL MIXING HEIGHTS

FOR EXAMPLE, |0|0|1|4|0|3| WOULD BE READ BY CDM-QC AS 14,030 METERS.

PLEASE PLACE YOUR FIGURE HERE; USE NO DECIMAL POINT. ENTER THIS NUMBER IN COLUMNS 19-24 AND 25-30 OF CARD 4, FOR ALL FIVE CDM-QC RUNS. SEE STEP 4.

|0| | | | | |	|0| | | | | |
AFTERNOON	NOCTURNAL (MORNING)

WORKSHEET 5 (FOR STEP 5) FILLED OUT BY: ____________ DATE ________ PG ___ OF ___

MONITORING STATION DATA

NAME OF STATION	STATION I.D. NUMBER (FOUR DIGITS)*	UTM LOCATION (NORMALIZED) IN km TO ONE DECIMAL PLACE XXXX.X		MEASURED CONCENTRATIONS, ANNUAL ARITHMETIC MEAN (μg/m³)		STANDARD 24-HR GEOMETRIC DEVIATIONS (μg/m³)	
		EASTING	NORTHING	SO_2	PART	SO_2	PART

*MAXIMUM OF 50 STATIONS.

WORKSHEET 6 (FOR STEP 6) FILLED OUT BY: ____________________ DATE ________ PG ___

EMISSION INVENTORY POINT SOURCES OF ___

NAME OF POINT SOURCE	POINT SOURCE ID NUMBER (FIVE DIGITS)	UTM LOCATION (NORMALIZED) IN km		EMISSION RATE (g/s)		STACK HEIGHT (m)	STACK DIAMETER (m)	EXIT VELOCITY OF STACK GASES (m/s)	TEMP. OF STACK GASES (°C)
		EASTING	NORTHING	SO_2	PART				

WORKSHEET 7 (FOR STEP 6) FILLED OUT BY:____________DATE:__________ PG____
EMISSION INVENTORY AREA SOURCES OF____

AREA SOURCE I.D. NUMBER FROM EMISSION INVENTORY (5 DIGITS)	UTM LOCATION (NORMALIZED) OF S.W. CORNER OF THE GRID SQUARE (km)		WIDTH OF THE GRID SQUARE (m)	EMISSION RATE (g/s)		ESTIMATED AVERAGE STACK HEIGHT (m)
	EASTING	NORTHING		SO_2	PART	

WORKSHEET 8 (FOR STEP 6) FILLED OUT BY: ________________ DATE __________ PG ___ OF ___

EMISSION INVENTORY DATA FOR STEP 24

POINT SOURCE NAME	POINT SOURCE I.D. NUMBER (FROM WORKSHEET 6)	SIMPLIFIED LAND USE ZONING CLASS*	EMISSION RATE OF POINT SOURCE (A) IN g/s		LAND AREA OF POINT SOURCE (B) IN ha	EMISSION DENSITY (A ÷ B) IN (g/s)/ha	
			SO_2	PART		SO_2	PART

*LIST ALL POINT SOURCES IN A GIVEN ZONING CLASS CONSECUTIVELY.

WORKSHEET 9 (FOR STEP 7) FILLED OUT BY:__________ DATE:__________ PG____

AREA SOURCE EXEMPTIONS OF____

AREA SOURCE ID NUMBER* (5 DIGITS)	UTM LOCATION (NORMALIZED) OF S.W. CORNER OF THE GRID SQUARE (km)		WIDTH OF THE GRID SQUARE (m)	FUTURE EMISSION RATE (g/s)		AVERAGE STACK HEIGHT (m)
	EASTING	NORTHING		SO_2	PART	

*PROBABLY AN AREA SOURCE GRID SQUARE NUMBER FROM THE EMISSION INVENTORY.

WORKSHEET 10 (FOR STEP 7) FILLED OUT BY: ____________________ DATE ________ PG ___
EXISTING POINT SOURCE EXEMPTIONS OF ___

NAME OF POINT SOURCE	POINT SOURCE ID NUMBER (FIVE DIGITS)	UTM LOCATION (NORMALIZED) IN km		FUTURE EMISSION RATE (g/s)		STACK HEIGHT (m)	STACK DIAMETER (m)	EXIT VELOCITY OF STACK GASES (m/s)	TEMP OF STACK GASES (°C)
		EASTING	NORTHING	SO_2	PART				

WORKSHEET II (FOR STEP 8) FILLED OUT BY:________________DATE________ PG____

STACK HEIGHTS FOR AIR QUALITY RUNS OF____

POINT SOURCE NAME	POINT SOURCE NUMBER (FROM WORKSHEET 6)	SIMPLIFIED LAND USE ZONING CLASS	STACK HEIGHT FROM WORKSHEET 6 (m)

WORKSHEET 12 (FOR STEP 20) FILLED OUT BY: ____________________ DATE ________ PG ___

CONVERTING GEOMETRIC MEANS TO ARITHMETIC MEANS FOR PARTICULATES OF ___

RECEPTOR NUMBER	A AIR QUALITY STD APPLICABLE AT RECEPTOR, ANNUAL GEOMETRIC MEAN, IN $\mu g/m^3$ (Mg)	B STD GEOMETRIC DEVIATION (24 HR) AT RECEPTOR, IN $\mu g/m^3$ (Sg)	SQUAREROOT OF Sg ($\sqrt{Sg}$)	C NATURAL LOGARITHMS OF SQUAREROOT OF Sg ($\ln\sqrt{Sg}$)	D COLUMN B RAISED TO THE COLUMN C POWER ($Sg^{\ln\sqrt{Sg}}$)	ANNUAL ARITHMETIC MEAN, IN $\mu g/m^3$ (COL. A X COL. D) $\chi = Mg\, Sg^{\ln\sqrt{Sg}}$

WORKSHEET 13 (FOR STEP 20) FILLED OUT BY: ________ DATE: ________ RIGHT-HAND-SIDE VALUES	PG ____ OF ____

RECEPTOR NAME	RECEPTOR NUMBER (ROW)	AIR POLLUTANT CONCENTRATIONS ($\mu g/m^3$)					
		CALIBRATED AIR QUALITY STANDARD (A)		AIR QUALITY IMPACT OF EXEMPT SOURCES (B)		RIGHT-HAND-SIDE VALUE (A-B)	
		SO_2	PART	SO_2	PART	SO_2	PART

WORKSHEET 14 (FOR STEP 24) FILLED OUT BY: ________________ DATE: _____ PG___ OF___

FINDING THE POTENTIAL EMISSIONS OF EDZ SOURCES PER km^2

COLUMN NUMBERS FROM LP OUTPUT OR MATRIX	EXPLANATION OF COLUMNS[a]	ACTIVITIES X INPUT COST = EMISSIONS PER EDZ GRID SQUARE PER LAND USE CLASS (g/s)[b]		EMISSIONS OF FUTURE EDZ SOURCES LOCATED IN EACH EDZ GRID SQUARE IF FUTURE CONSTRUCTION USES ALL OF THE EDL ALLOCATED (g/s)[c]	
		SO_2	PART	SO_2	PART

[a] From LP matrix. The "explanation" for each column number consists of an EDZ grid square number and a land use class.

[b] From LP output; see text.

[c] The number of entries in this column will equal the number of EDZ grid squares included in the LP matrix.

WORKSHEET 15 (FOR STEP 24) FILLED OUT BY:________________ DATE ______ PG___
COMPARISON OF TOTAL EMISSIONS WITHIN EACH SQUARE KILOMETER OF___

EDZ GRID SQUARE NUMBERS	EMISSIONS OF EXEMPT POINT SOURCES LOCATED IN EACH EDZ GRID SQUARE (g/s)[a] A		EMISSIONS OF EXEMPT AREA SOURCES LOCATED IN EACH EDZ GRID SQUARE (g/s)[b] B		EMISSIONS OF FUTURE EDZ SOURCES LOCATED IN EACH EDZ GRID SQUARE IF FUTURE CONSTRUCTION USES ALL OF THE EDL ALLOCATED (g/s)[c] C		TOTAL POTENTIAL EMISSIONS FROM EACH EDZ GRID SQUARE (g/s) D = A + B + C D		AREA OF EDZ GRID SQUARE (km^2) E	TOTAL EMISSIONS FROM EACH km^2 F = D ÷ E F	
	SO_2	PART	SO_2	PART	SO_2	PART	SO_2	PART		SO_2	PART

[a] Exempt sources from Step 7 are mapped onto the general regional map and the emissions of the exempt sources are summed for each EDZ grid square. The results are placed in Column B. Use the gridded zoning maps from Step 2 to assist in locating the exempt sources.

[b] From the emission inventory (Step 6). Emissions from each emission inventory grid square are reallocated to the appropriate km^2 grids.

[c] From final column of Worksheet 14.

APPENDIX K: THE CLEANAIR CITY TEST CASE

The Cleanair City Test Case was created to test the methodology and provide a sample problem showing how each guidebook step would be completed in a somewhat real situation. Each step has been followed as if we, the authors, were setting emission density limits for this community. The test case presents each step of the guidebook methodology, in sequence, showing the maps, completed worksheets, and calculations that would be required to set EDLs for Cleanair City. We have attempted to make the problem as small as possible to allow you to take our data and quickly run through the methodology. It should not take very long to complete, provided the dispersion model and linear programming package are available and ready for use.

While the EDZ guidebook is intended for use on the regional level, the test case example sets EDLs only for the City of Cleanair. Beyond the mapping and gridding procedures in Steps 1 and 2,* the region is ignored, in order to decrease the size and complexity of the problem. We would like to stress that this purely local analysis is not the normal use of the guidebook, but is only done as a matter of convenience.

The test case was developed from a diverse data base.** Cleanair City, which has a population of about 40,000, lies in the center of a small three-county region and is surrounded by a few satellite communities, a large lake, and a number of farms. Five major polluting industries are located in Cleanair; their characteristics are shown in Table 31.

Table 31. Cleanair City Industry

Industry	Products	Employment
Vespucci Industries	Plastic packaging	50
Columbus, Inc.	Vinyl sheeting, film, plastic wraps	750
Drake-Magellan & Co.	Laundry and drycleaning equipment, sheet metal fixtures	700
Prince Henry's Navigation, Amal.	Small boats, roofing and building materials	900
Cook's Corp.	Farm Equipment, tractors	4,400

---

*These could only be adequately illustrated on the regional scale.

**Although the UTM coordinates place Cleanair in Moline, Illinois, Cleanair City's characteristics are not those of Moline.

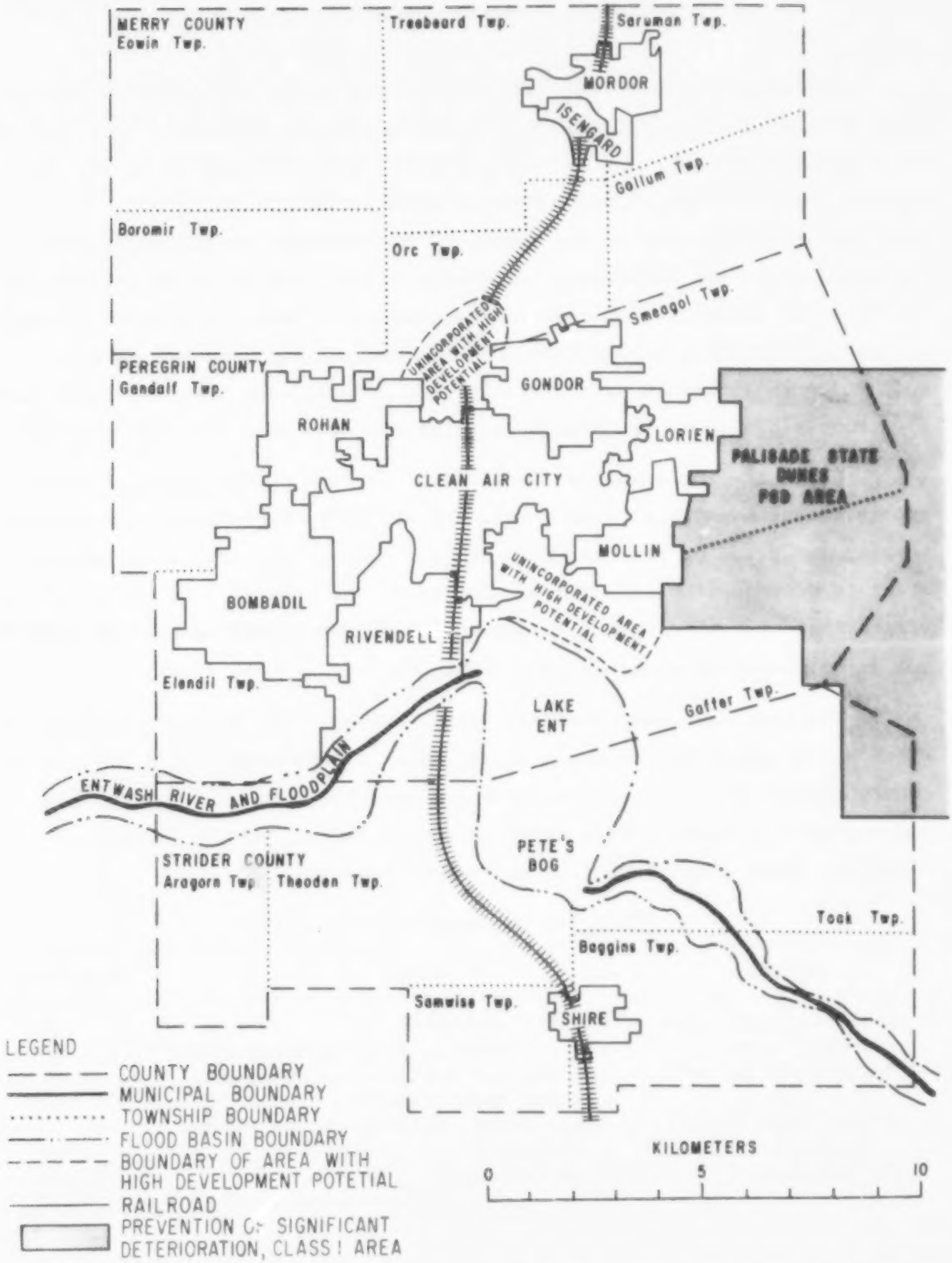

MERRY COUNTY
Eowin Twp.
Treebeard Twp.
Saruman Twp.
MORDOR
ISENGARD
Gollum Twp.
Boromir Twp.
Orc Twp.
Smeagol Twp.
UNINCORPORATED AREA WITH HIGH DEVELOPMENT POTENTIAL
PEREGRIN COUNTY
Gandalf Twp.
ROHAN
GONDOR
LORIEN
PALISADE STATE DUNES PSD AREA
CLEAN AIR CITY
MOLLIN
UNINCORPORATED AREA WITH HIGH DEVELOPMENT POTENTIAL
BOMBADIL
RIVENDELL
Elendil Twp.
LAKE ENT
Goffer Twp.
ENTWASH RIVER AND FLOODPLAIN
PETE'S BOG
STRIDER COUNTY
Aragorn Twp.
Theoden Twp.
Took Twp.
Baggins Twp.
Samwise Twp.
SHIRE
LEGEND
COUNTY BOUNDARY
MUNICIPAL BOUNDARY
TOWNSHIP BOUNDARY
FLOOD BASIN BOUNDARY
BOUNDARY OF AREA WITH HIGH DEVELOPMENT POTETIAL
RAILROAD
PREVENTION OF SIGNIFICANT DETERIORATION, CLASS I AREA
KILOMETERS
0
5
10

Fig. 125. Step 1: General Regional Map for Cleanair [The only item produced in Step 1 is this map. The map features shown here are the minimum required.]

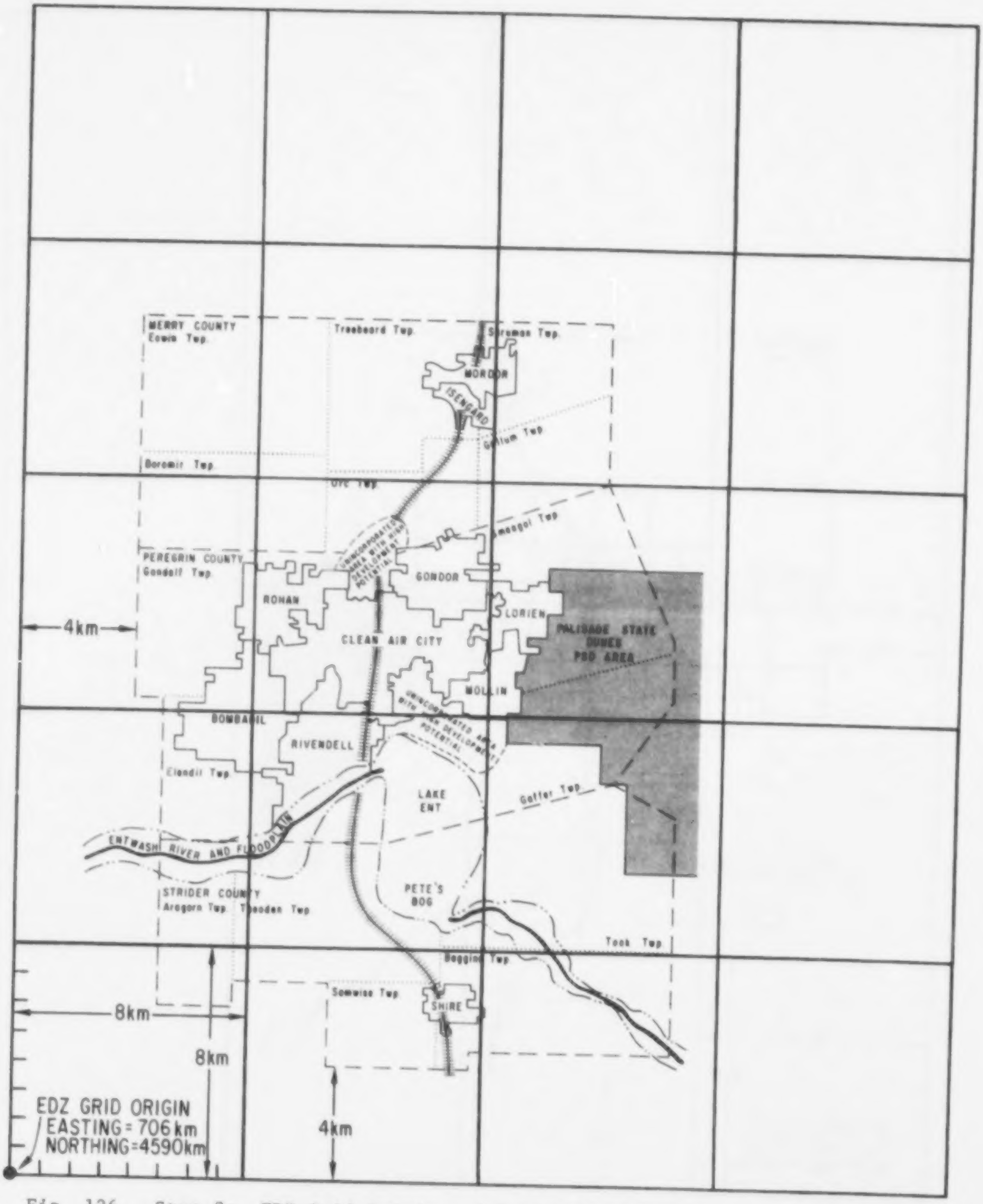

MERRY COUNTY
Eowin Twp.
Treebeard Twp.
Stroman Twp.
MORDOR
ISENGARD
Gollum Twp.
Boromir Twp.
Orc Twp.
UNINCORPORATED AREA WITH HIGH DEVELOPMENT POTENTIAL
Smeagol Twp.
PEREGRIN COUNTY
Gandalf Twp.
ROHAN
GONDOR
LORIEN
PALISADE STATE DUNES PSD AREA
4km
CLEAN AIR CITY
MOLLIN
BOMBADIL
RIVENDELL
UNINCORPORATED AREA WITH HIGH DEVELOPMENT POTENTIAL
Elendil Twp.
LAKE ENT
Gaffer Twp.
ENTWASH RIVER AND FLOODPLAIN
STRIDER COUNTY
Aragorn Twp.
Theoden Twp.
PETE'S BOG
Took Twp.
Baggins Twp.
Samwise Twp.
SHIRE
8km
8km
4km
EDZ GRID ORIGIN
EASTING = 706 km
NORTHING = 4590 km

Fig. 126. Step 2: EDZ Grid Origin and 8 km Grids for Cleanair [Note the 4 km spacing to the south and west between the regional boundary and the grid origin.]

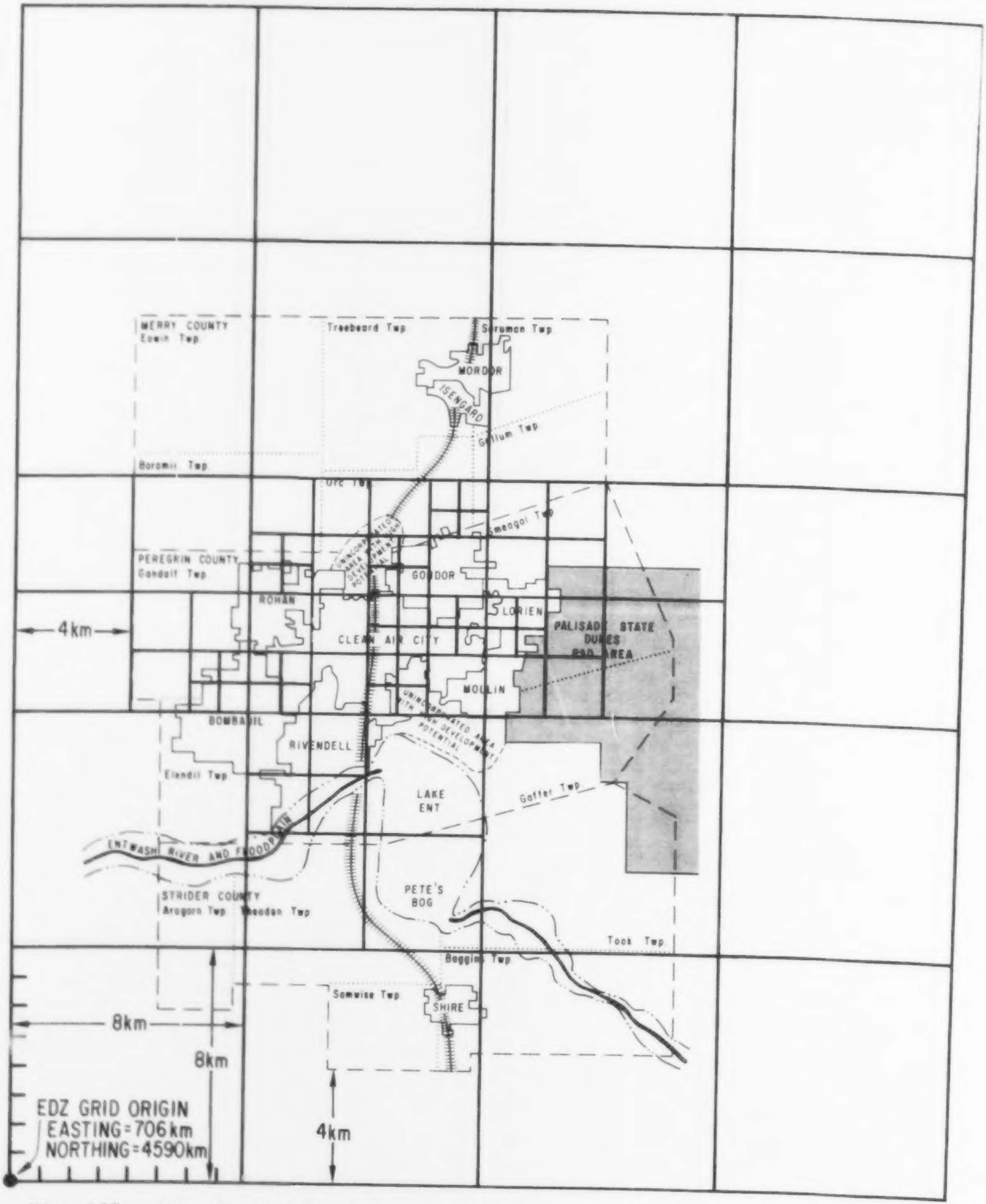
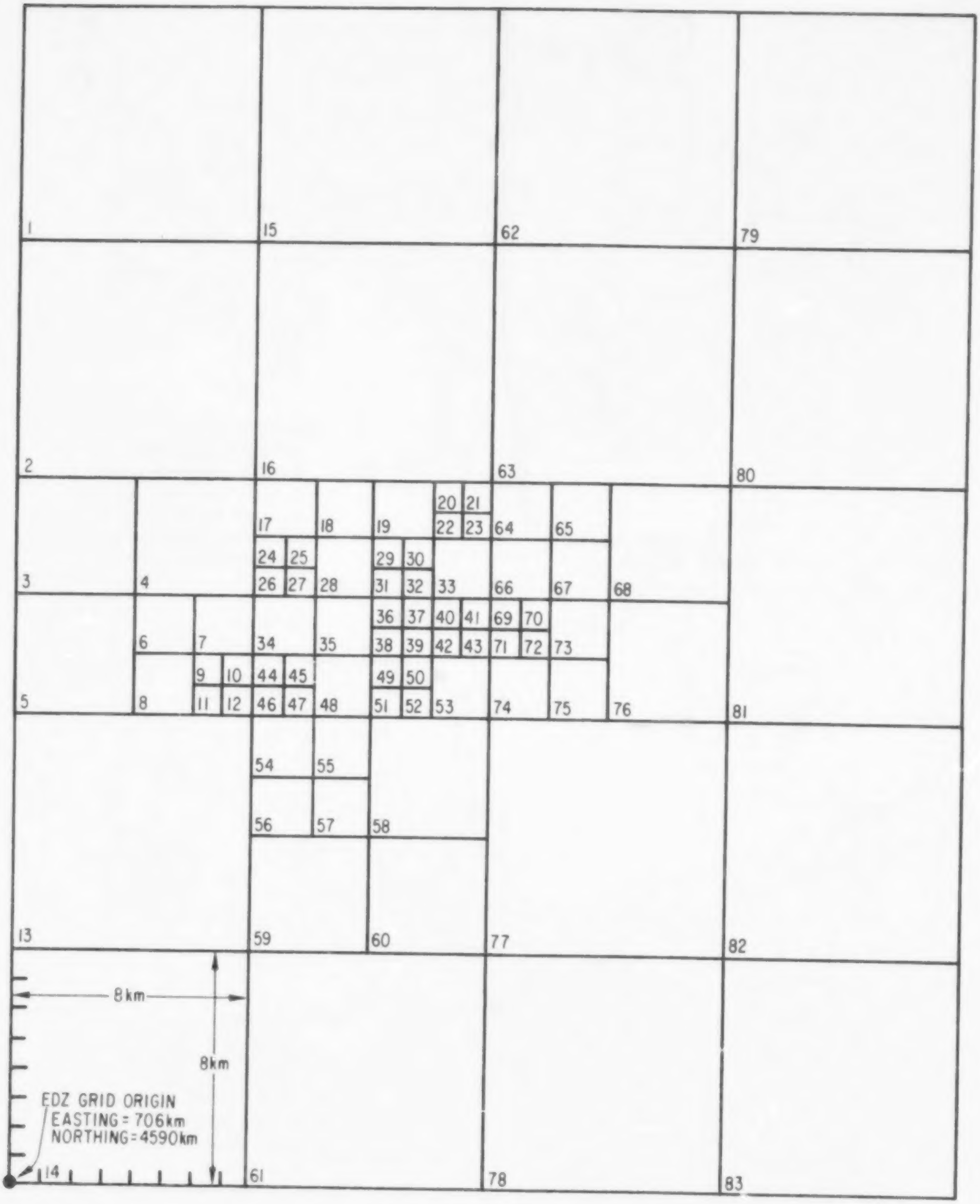

MERRY COUNTY
Eowin Twp
Treebeard Twp
Saruman Twp
MORDOR
ISENGARD
Gollum Twp
Boromir Twp
Orc Twp
Smeagol Twp
PEREGRIN COUNTY
Gandalf Twp
UNINCORPORATED AREA WITH DEVELOPMENT POTENTIAL
GONDOR
ROHAN
LORIEN
4km
CLEAN AIR CITY
PALISADE STATE DUNES 230 AREA
MOULIN
UNINCORPORATED AREA WITH HIGH DEVELOPMENT POTENTIAL
BOMBADIL
RIVENDELL
Elendil Twp
LAKE ENT
Gaffer Twp
ENTWASH RIVER AND FLOODPLAIN
PETE'S BOG
STRIDER COUNTY
Aragorn Twp
Woodan Twp
Took Twp
Baggins Twp
Samwise Twp
SHIRE
8km
8km
4km
EDZ GRID ORIGIN
EASTING=706km
NORTHING=4590km

Fig. 127. Step 2: Subdivided EDZ Grid System for Cleanair [This is the final "EDZ Grid System" for Cleanair. To streamline the problem, far fewer than 350 squares were used.]


1
15
62
79
2
16
63
80
3
4
17
18
19
20
21
22
23
64
65
24
25
26
27
28
29
30
31
32
33
66
67
68
5
6
7
8
9
10
11
12
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35
36
37
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39
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41
42
43
44
45
46
47
48
49
50
51
52
53
69
70
71
72
73
74
75
76
81
54
55
56
57
58
13
59
60
77
82
8km
8km
EDZ GRID ORIGIN
EASTING = 706km
NORTHING = 4590km
14
61
78
83

Fig. 128. Step 2: Numbered EDZ Grid System for Cleanair [Note: These grid square numbers are read as four digit codes, such as 0001 and 0026.]

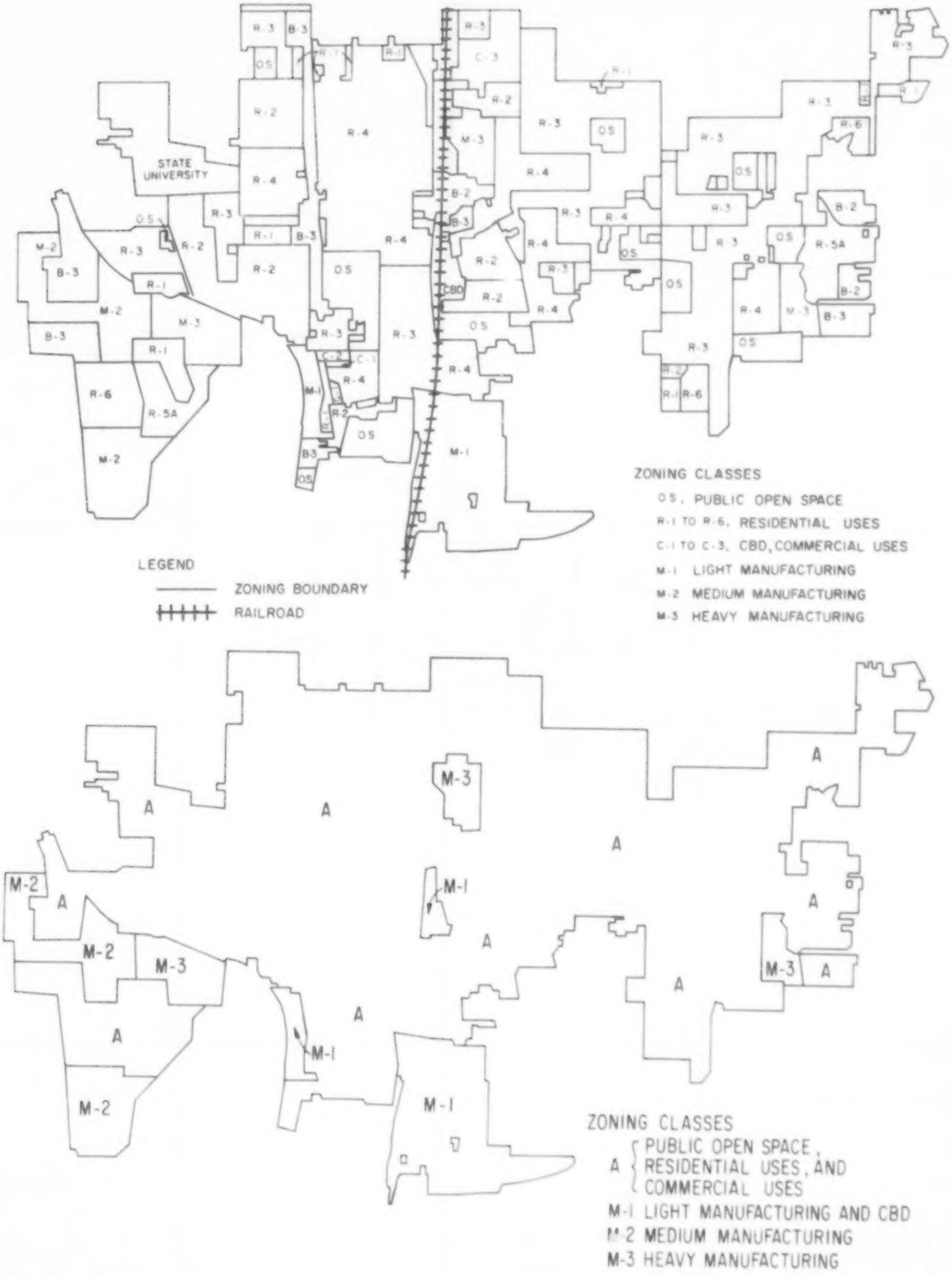

STATE UNIVERSITY
LEGEND
ZONING BOUNDARY
RAILROAD
ZONING CLASSES
O.S. PUBLIC OPEN SPACE
R-1 TO R-6, RESIDENTIAL USES
C-1 TO C-3, CBD, COMMERCIAL USES
M-1 LIGHT MANUFACTURING
M-2 MEDIUM MANUFACTURING
M-3 HEAVY MANUFACTURING
ZONING CLASSES
A PUBLIC OPEN SPACE, RESIDENTIAL USES, AND COMMERCIAL USES
M-1 LIGHT MANUFACTURING AND CBD
M-2 MEDIUM MANUFACTURING
M-3 HEAVY MANUFACTURING

Fig. 129. Step 2: Cleanair City Zoning Maps [The top map shows the city's land use zoning; the lower map is in the simplified form recommended for use in EDZ. From this point on in the test case, the analysis will be at the local level.]

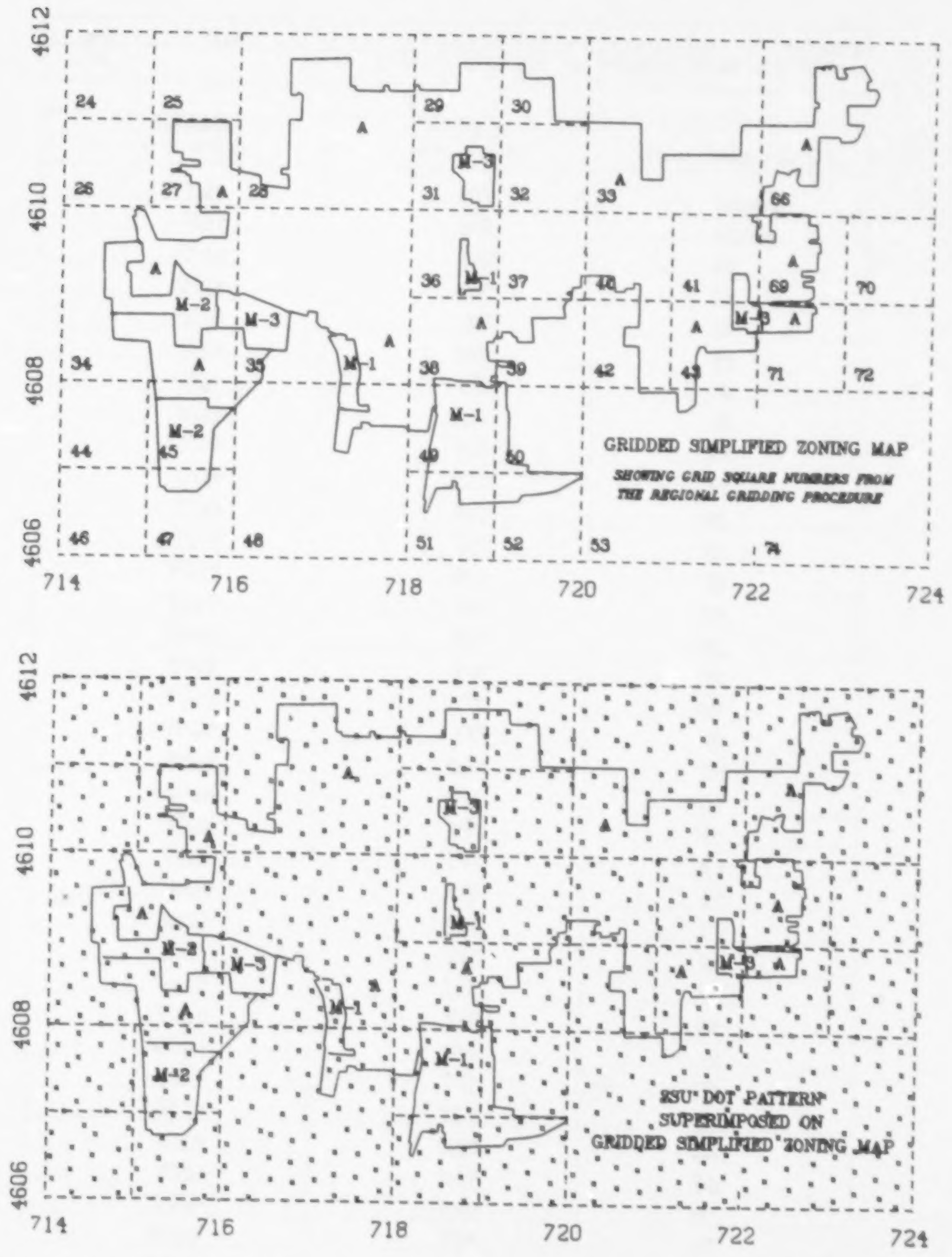
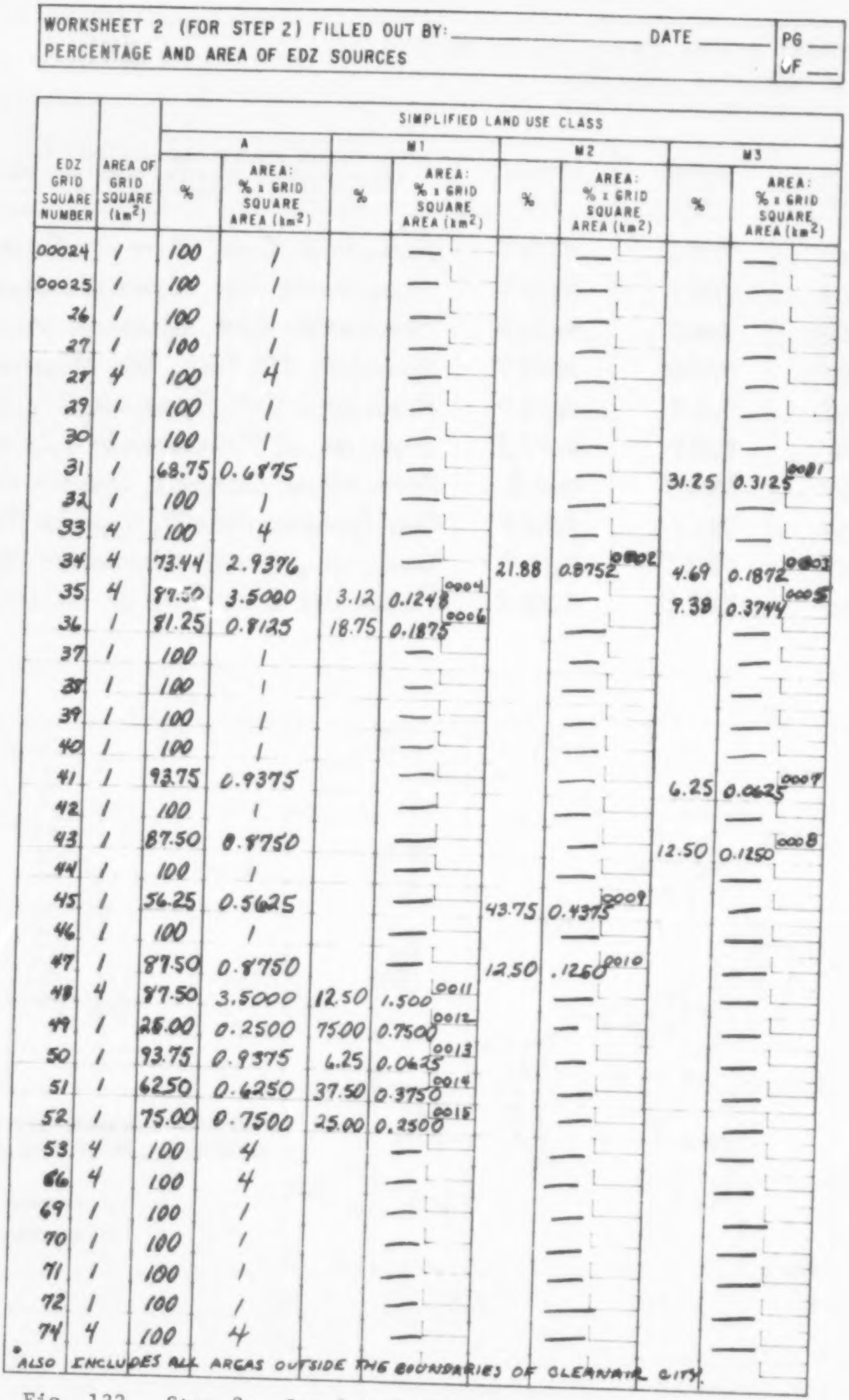

4612
4610
4608
4606
714
716
718
720
722
724
24
25
29
30
26
27
28
31
32
33
66
36
37
40
41
69
70
34
35
38
39
42
43
71
72
44
45
49
50
46
47
48
51
52
53
74
A
M-1
M-2
M-3
GRIDDED SIMPLIFIED ZONING MAP
SHOWING GRID SQUARE NUMBERS FROM THE REGIONAL GRIDDING PROCEDURE
SSU DOT PATTERN SUPERIMPOSED ON GRIDDED SIMPLIFIED ZONING MAP

Fig. 130. Step 2: Gridded Cleanair City Zoning Map with SSU Dot Pattern [Grid pattern from Figs. 127 and 128; SSU dot pattern less dense than recommended in Step 2 for simplicity.]

WORKSHEET 1 (FOR STEP 2) FILLED OUT BY: ______ DATE ______ LIST OF SOUTHWEST CORNERS OF EDZ GRID SQUARES	PG ___ OF ___

EDZ GRID SQUARE NUMBER	NORMALIZED NORTHING IN km	NORMALIZED EASTING IN km
00024	714	4611
00025	715	4611
26	714	4610
27	715	4610
28	716	4610
29	718	4611
30	719	4611
31	718	4610
32	719	4610
33	720	4610
34	714	4608
35	716	4608
36	718	4609
37	719	4609
38	718	4608
39	719	4608
40	720	4609
41	721	4609
42	720	4608
43	721	4608
44	714	4607
45	715	4607
46	714	4606
47	715	4606
48	716	4606
49	718	4607
50	719	4607
51	718	4606
52	719	4606
53	720	4606
66	722	4610
69	722	4609
70	723	4609
71	722	4608
72	723	4608
74	722	4606

Fig. 131. Step 2: Completed Worksheet 1 for Cleanair City



WORKSHEET 2 (FOR STEP 2) FILLED OUT BY: ____________ DATE ______ PG ___
PERCENTAGE AND AREA OF EDZ SOURCES OF ___

EDZ GRID SQUARE NUMBER	AREA OF GRID SQUARE (km^2)	SIMPLIFIED LAND USE CLASS										
		A		M1			M2			M3		
		%	AREA: % x GRID SQUARE AREA (km^2)	%	AREA: % x GRID SQUARE AREA (km^2)		%	AREA: % x GRID SQUARE AREA (km^2)		%	AREA: % x GRID SQUARE AREA (km^2)	
00024	1	100	1		—			—			—	
00025	1	100	1		—			—			—	
26	1	100	1		—			—			—	
27	1	100	1		—			—			—	
28	4	100	4		—			—			—	
29	1	100	1		—			—			—	
30	1	100	1		—			—			—	
31	1	68.75	0.6875		—			—		31.25	0.3125	0001
32	1	100	1		—			—			—	
33	4	100	4		—			—			—	
34	4	73.44	2.9376		—		21.88	0.8752	0002	4.69	0.1872	0003
35	4	87.50	3.5000	3.12	0.1248	0004		—		9.38	0.3744	0005
36	1	81.25	0.8125	18.75	0.1875	0006		—			—	
37	1	100	1		—			—			—	
38	1	100	1		—			—			—	
39	1	100	1		—			—			—	
40	1	100	1		—			—			—	
41	1	93.75	0.9375		—			—		6.25	0.0625	0007
42	1	100	1		—			—			—	
43	1	87.50	0.8750		—			—		12.50	0.1250	0008
44	1	100	1		—			—			—	
45	1	56.25	0.5625		—		43.75	0.4375	0009		—	
46	1	100	1		—			—			—	
47	1	87.50	0.8750		—		12.50	.1250	0010		—	
48	4	87.50	3.5000	12.50	1.500	0011		—			—	
49	1	25.00	0.2500	7500	0.7500	0012		—			—	
50	1	93.75	0.9375	6.25	0.0625	0013		—			—	
51	1	6250	0.6250	37.50	0.3750	0014		—			—	
52	1	75.00	0.7500	25.00	0.2500	0015		—			—	
53	4	100	4		—			—			—	
66	4	100	4		—			—			—	
69	1	100	1		—			—			—	
70	1	100	1		—			—			—	
71	1	100	1		—			—			—	
72	1	100	1		—			—			—	
74	4	100	4		—			—			—	

*ALSO INCLUDES ALL AREAS OUTSIDE THE BOUNDARIES OF CLEANAIR CITY.

Fig. 132. Step 2: Completed Worksheet 2 for Cleanair City

WORKSHEET 3 (FOR STEP 3) FILLED OUT BY ____________ DATE ________ PG ___
LIST OF RECEPTOR LOCATIONS OF ___

RECEPTOR NUMBER	EASTING IN km	NORTHING IN km	NOTES ON THE REASON FOR SELECTING THIS LOCATION FOR A RECEPTOR (CENTER, SENSITIVE, POLITICAL JURISDICTION, MONITORING SITE, ETC.)
0001	714.5	4610.8	POPULATION CTR, CITY OF ROHAN
0002	715.5	4610.5	MONITORING STN, STATE UNIVERSITY
0003	714.0	4606.0	POPULATION CTR, BOMBADIL VILLAGE
0004	717.0	4609.7	SENSITIVE, TB HOSP. SO_2 MONITOR
0005	718.5	4609.4	POPULATION CTR, CLEANAIR CITY, MON. STN.
0006	718.4	4607.3	MONITOR, 2ND + CHESTNUT STS., CLEANAIR
0007	720.9	4611.8	POPULATION CENTER, GONDOR ESTATES
0008	721.1	4607.0	FAST GROWING AREA #1, HIGH POP. POTENTIAL
0009	723.7	4610.9	SENSITIVE, LORIÉN COMMUNITY HOSPITAL
0010	722.8	4608.2	POPULATION CTR, CITY OF HOLLIN

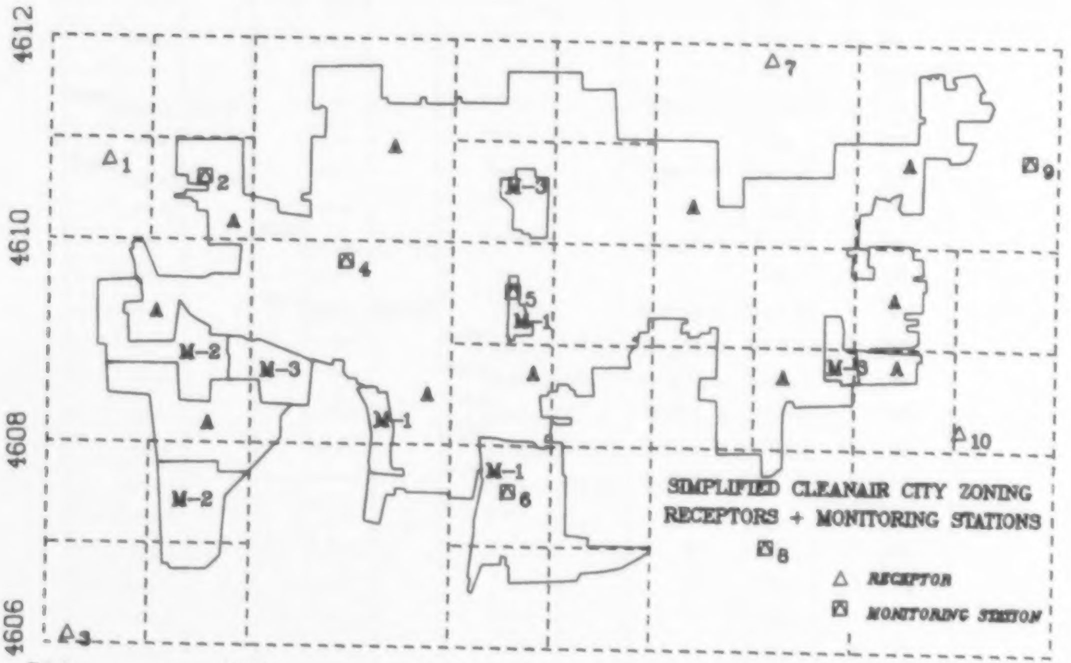

4612
4610
4608
4606
714
716
718
720
722
724
1
2
3
4
5
6
7
8
9
10
M-1
M-2
M-3
SIMPLIFIED CLEANAIR CITY ZONING
RECEPTORS + MONITORING STATIONS
RECEPTOR
MONITORING STATION

Fig. 133. Step 3: Completed Worksheet 3 and Receptor Point Map for Cleanair City [Note: Monitoring stations are used as receptor points.]

WORKSHEET 4 (FOR STEP 4) FILLED OUT BY ______ DATE ______ PG 1
METEOROLOGICAL DATA OF 1

THIS WORKSHEET SHOWS THE EXACT FORMAT THAT THE METEOROLOGICAL DATA MUST BE IN FOR INPUT TO CDM-QC.

1. MEAN ANNUAL ATMOSPHERIC TEMPERATURE

FOR EXAMPLE, |0|0|1|3|8|3| WOULD BE READ BY CDM-QC AS 13.83° CELSIUS.

PLEASE PLACE YOUR FIGURE HERE; USE NO DECIMAL POINT. ENTER THIS NUMBER IN COLUMNS 61-66 OF CARD 4, FOR ALL FIVE CDM-QC RUNS. SEE STEP 9.

|0|0|1|0|0|9|

2. MEAN ANNUAL MIXING HEIGHTS

FOR EXAMPLE, |0|1|4|0|3|0| WOULD BE READ BY CDM-QC AS 14,030 METERS.

PLEASE PLACE YOUR FIGURE HERE; USE NO DECIMAL POINT. ENTER THIS NUMBER IN COLUMNS 19-24 AND 25-30 OF CARD 4, FOR ALL FIVE CDM-QC RUNS. SEE STEP 4.

|0|1|1|9|0|0|	|0|0|0|3|9|5|
AFTERNOON	NOCTURNAL (MORNING)

Fig. 134. Step 4: Completed Worksheet 4 for Cleanair City

```
                         C L I M A T O L O G I C A L   D I S P E R S I O N   M O D E L

                  LIGHT MANUFACTURING AIR QUALITY RUN OF CDM-QC FOR THE CLEANAIR CITY EXAMPLE
                                                RUN     1

                                   METEOROLOGICAL JOINT FREQUENCY FUNCTION

STABILITY CLASS 1                                       W I N D   S P E E D   C L A S S

   WIND DIRECTION    SECTOR              1            2            3            4            5            6

         N              1            0.004452     0.000228     0.0          0.0          0.0          0.0
         NNE            2            0.0          0.000114     0.0          0.0          0.0          0.0
         NE             3            0.0          0.000228     0.0          0.0          0.0          0.0
         ENE            4            0.0          0.000114     0.0          0.0          0.0          0.0
         E              5            0.000228     0.000457     0.0          0.0          0.0          0.0
         ESE            6            0.000342     0.000457     0.0          0.0          0.0          0.0
         SE             7            0.0          0.000342     0.0          0.0          0.0          0.0
         SSE            8            0.0          0.000114     0.0          0.0          0.0          0.0
         S              9            0.0          0.000114     0.0          0.0          0.0          0.0
         SSW           10            0.0          0.000457     0.0          0.0          0.0          0.0
         SW            11            0.000114     0.000228     0.0          0.0          0.0          0.0
         WSW           12            0.0          0.000114     0.0          0.0          0.0          0.0
         W             13            0.000114     0.000228     0.0          0.0          0.0          0.0
         WNW           14            0.000114     0.000114     0.0          0.0          0.0          0.0
         NW            15            0.0          0.000114     0.0          0.0          0.0          0.0
         NNW           16            0.000114     0.000457     0.0          0.0          0.0          0.0

STABILITY CLASS 2                                       W I N D   S P E E D   C L A S S

   WIND DIRECTION    SECTOR              1            2            3            4            5            6

         N              1            0.003425     0.002169     0.001370     0.0          0.0          0.0
         NNE            2            0.000342     0.001256     0.000799     0.0          0.0          0.0
         NE             3            0.000571     0.001142     0.000228     0.0          0.0          0.0
         ENE            4            0.000457     0.001484     0.001142     0.0          0.0          0.0
         E              5            0.001941     0.001370     0.001598     0.0          0.0          0.0
         ESE            6            0.001027     0.001142     0.000457     0.0          0.0          0.0
         SE             7            0.000342     0.001142     0.000685     0.0          0.0          0.0
         SSE            8            0.000571     0.001826     0.001598     0.0          0.0          0.0
         S              9            0.000685     0.001826     0.002511     0.0          0.0          0.0
         SSW           10            0.000685     0.001484     0.000913     0.0          0.0          0.0
         SW            11            0.000685     0.001598     0.001598     0.0          0.0          0.0
         WSW           12            0.000571     0.001484     0.000913     0.0          0.0          0.0
         W             13            0.001142     0.002740     0.001941     0.0          0.0          0.0
         WNW           14            0.001027     0.002169     0.000913     0.0          0.0          0.0
         NW            15            0.000342     0.001712     0.001027     0.0          0.0          0.0
         NNW           16            0.000228     0.001712     0.001256     0.0          0.0          0.0
```

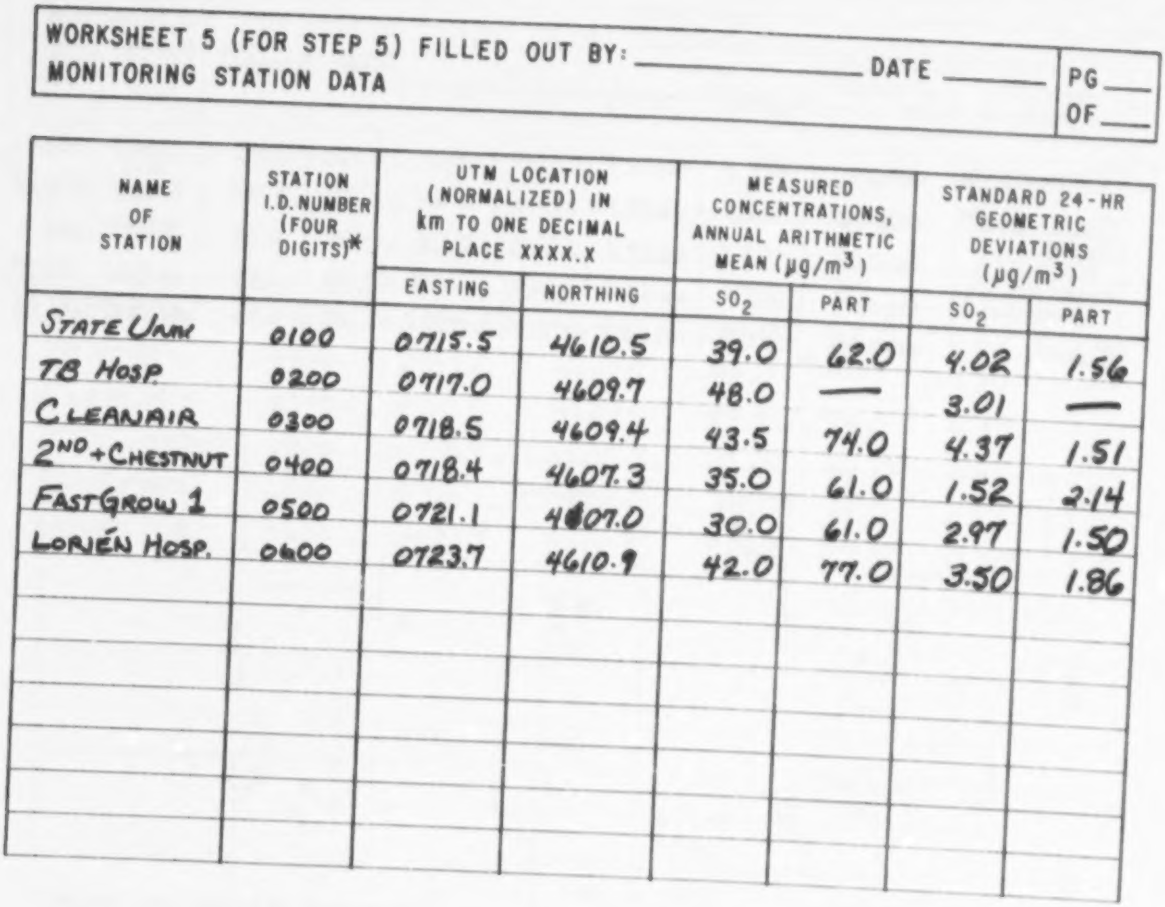
Fig. 135. Step 4: Joint Frequency Function for Cleanair City (continued on pages 293 and 294)

```
                         C L I M A T O L O G I C A L   D I S P E R S I O N   M O D E L
          LIGHT MANUFACTURING AIR QUALITY RUN OF CDM-QC FOR THE CLEANAIR CITY EXAMPLE
                                         RUN    1

                              METEOROLOGICAL JOINT FREQUENCY FUNCTION

STABILITY CLASS 3
                                                      W I N D   S P E E D   C L A S S
   WIND DIRECTION    SECTOR            1          2          3          4          5          6

        N               1          0.006279   0.001712   0.002626   0.000685   0.0        0.0
        NNE             2          0.000457   0.001027   0.001370   0.000228   0.0        0.0
        NE              3          0.000114   0.000457   0.000685   0.000457   0.0        0.0
        ENE             4          0.000342   0.001142   0.002169   0.000114   0.0        0.0
        E               5          0.000799   0.001941   0.003653   0.000457   0.0        0.0
        ESE             6          0.001142   0.002283   0.002968   0.000342   0.0        0.0
        SE              7          0.000228   0.001826   0.005822   0.000342   0.0        0.0
        SSE             8          0.000228   0.002055   0.004680   0.000685   0.0        0.0
        S               9          0.000342   0.002854   0.009475   0.001712   0.0        0.0
        SSW            10          0.000342   0.001027   0.004452   0.000342   0.0        0.0
        SW             11          0.000457   0.001826   0.005251   0.000685   0.0        0.0
        WSW            12          0.000457   0.002055   0.003082   0.000799   0.0        0.0
        W              13          0.001142   0.002511   0.004566   0.001027   0.0        0.0
        WNW            14          0.001256   0.002169   0.004338   0.000799   0.0        0.0
        NW             15          0.000114   0.002169   0.005251   0.000571   0.0        0.0
        NNW            16          0.0        0.000571   0.002968   0.000228   0.0        0.0

STABILITY CLASS 4
                                                      W I N D   S P E E D   C L A S S
   WIND DIRECTION    SECTOR            1          2          3          4          5          6

        N               1          0.003311   0.001712   0.006050   0.005594   0.000342   0.0
        NNE             2          0.000342   0.002626   0.003539   0.002397   0.0        0.0
        NE              3          0.000114   0.002055   0.001941   0.000913   0.0        0.0
        ENE             4          0.000228   0.002283   0.002511   0.000685   0.0        0.0
        E               5          0.000228   0.005708   0.008105   0.004224   0.000342   0.0
        ESE             6          0.000228   0.006393   0.004909   0.006621   0.000913   0.000228
        SE              7          0.0        0.003995   0.006507   0.009132   0.001027   0.0
        SSE             8          0.000114   0.003196   0.006963   0.009475   0.001598   0.0
        S               9          0.000457   0.004339   0.009703   0.012100   0.002283   0.000342
        SSW            10          0.000114   0.001712   0.003539   0.002397   0.000228   0.0
        SW             11          0.000228   0.003082   0.003767   0.003196   0.000799   0.000457
        WSW            12          0.000228   0.003767   0.003995   0.004909   0.001027   0.000799
        W              13          0.000114   0.004338   0.006849   0.008904   0.004110   0.001142
        WNW            14          0.000342   0.003767   0.007078   0.012100   0.002740   0.000913
        NW             15          0.000114   0.004452   0.006164   0.010845   0.001484   0.0
        NNW            16          0.000114   0.002055   0.004680   0.004224   0.000228   0.0
```

Fig. 135. Step 4: Joint Frequency Function for Cleanair City (continued)

```
                    C L I M A T O L O G I C A L   D I S P E R S I O N   M O D E L

          LIGHT MANUFACTURING AIR QUALITY RUN OF CDM-QC FOR THE CLEANAIR CITY EXAMPLE
                                          RUN     1

                              METEOROLOGICAL JOINT FREQUENCY FUNCTION

STABILITY CLASS 5                                      W I N D   S P E E D   C L A S S

  WIND DIRECTION    SECTOR           1           2           3           4           5           6

         N             1         0.004110    0.002055    0.008333    0.004909    0.000228    0.000228
         NNE           2         0.000228    0.002283    0.004224    0.001826    0.0         0.0
         NE            3         0.000228    0.001598    0.003196    0.000228    0.0         0.0
         ENE           4         0.000114    0.001826    0.002968    0.000685    0.0         0.0
         E             5         0.000571    0.003082    0.010274    0.002626    0.000114    0.0
         ESE           6         0.000685    0.003425    0.008447    0.004795    0.000685    0.000114
         SE            7         0.0         0.002055    0.011301    0.007991    0.000342    0.0
         SSE           8         0.0         0.001598    0.008447    0.010274    0.001598    0.000114
         S             9         0.000114    0.001484    0.013014    0.011073    0.000913    0.0
         SSW          10         0.000114    0.001027    0.003881    0.001256    0.000228    0.0
         SW           11         0.000228    0.000457    0.002854    0.001370    0.000342    0.000228
         WSW          12         0.000342    0.000913    0.002397    0.004680    0.002055    0.000457
         W            13         0.000342    0.001598    0.004110    0.009932    0.002740    0.001826
         WNW          14         0.000571    0.001712    0.004795    0.011530    0.002511    0.001256
         NW           15         0.000457    0.002397    0.006279    0.009361    0.001370    0.0
         NNW          16         0.000114    0.001484    0.006393    0.006849    0.0         0.0

STABILITY CLASS 6                                      W I N D   S P E E D   C L A S S

  WIND DIRECTION    SECTOR           1           2           3           4           5           6

         N             1         0.047146    0.004909    0.001826    0.0         0.0         0.0
         NNE           2         0.000457    0.006507    0.001142    0.0         0.0         0.0
         NE            3         0.002511    0.004909    0.000571    0.0         0.0         0.0
         ENE           4         0.001484    0.005137    0.001826    0.0         0.0         0.0
         E             5         0.002740    0.012215    0.003995    0.0         0.0         0.0
         ESE           6         0.005365    0.017466    0.003425    0.0         0.0         0.0
         SE            7         0.002854    0.015982    0.006050    0.0         0.0         0.0
         SSE           8         0.000913    0.009247    0.011073    0.0         0.0         0.0
         S             9         0.000571    0.016667    0.022831    0.0         0.0         0.0
         SSW          10         0.000571    0.006279    0.003881    0.0         0.0         0.0
         SW           11         0.001027    0.008333    0.004566    0.0         0.0         0.0
         WSW          12         0.003082    0.009132    0.002968    0.0         0.0         0.0
         W            13         0.004338    0.011530    0.006393    0.0         0.0         0.0
         WNW          14         0.002055    0.009703    0.004338    0.0         0.0         0.0
         NW           15         0.000913    0.005365    0.003196    0.0         0.0         0.0
         NNW          16         0.001256    0.005023    0.001826    0.0         0.0         0.0
```

Fig. 135. Step 4: Joint Frequency Function for Cleanair City (continued)



WORKSHEET 5 (FOR STEP 5) FILLED OUT BY: ____________ DATE ________ PG ___

MONITORING STATION DATA OF ___

NAME OF STATION	STATION I.D. NUMBER (FOUR DIGITS)*	UTM LOCATION (NORMALIZED) IN km TO ONE DECIMAL PLACE XXXX.X		MEASURED CONCENTRATIONS, ANNUAL ARITHMETIC MEAN (μg/m³)		STANDARD 24-HR GEOMETRIC DEVIATIONS (μg/m³)	
		EASTING	NORTHING	SO_2	PART	SO_2	PART
STATE UNIV	0100	0715.5	4610.5	39.0	62.0	4.02	1.56
TB HOSP.	0200	0717.0	4609.7	48.0	—	3.01	—
CLEANAIR	0300	0718.5	4609.4	43.5	74.0	4.37	1.51
2ND + CHESTNUT	0400	0718.4	4607.3	35.0	61.0	1.52	2.14
FASTGROW 1	0500	0721.1	4607.0	30.0	61.0	2.97	1.50
LORIÉN HOSP.	0600	0723.7	4610.9	42.0	77.0	3.50	1.86

Fig. 136. Step 5: Completed Worksheet 5 for Cleanair City (Data were taken from U.S. EPA data files. Monitoring station locations are mapped in Fig. 133.]

WORKSHEET 6 (FOR STEP 6) FILLED OUT BY: ____________________ DATE __________ PG ____
EMISSION INVENTORY POINT SOURCES OF ____

NAME OF POINT SOURCE	POINT SOURCE ID NUMBER (FIVE DIGITS)	UTM LOCATION (NORMALIZED) IN km		EMISSION RATE (g/s)		STACK HEIGHT (m)	STACK DIAMETER (m)	EXIT VELOCITY OF STACK GASES (m/s)	TEMP. OF STACK GASES (°C)
		EASTING	NORTHING	SO_2	PART				
Vespucci Co.	00001	715.9	4608.7	0.0679	0.0065	38.10	1.83	0.369	204.81
Columbus Inc	00002	715.5	4607.1	1.7310	0.3600	53.34	2.44	0.408	276.85
Drake-Magellan	00003	718.5	4607.2	2.3320	0.0683	44.50	2.18	3.881	204.11
Prince Henry's Navagation	00004	716.4	4608.4	7.0900	1.3240	45.72	1.83	10.240	82.25
Cook's	00005	718.8	4610.2	2.7620	0.2362	41.25	1.55	26.960	166.85

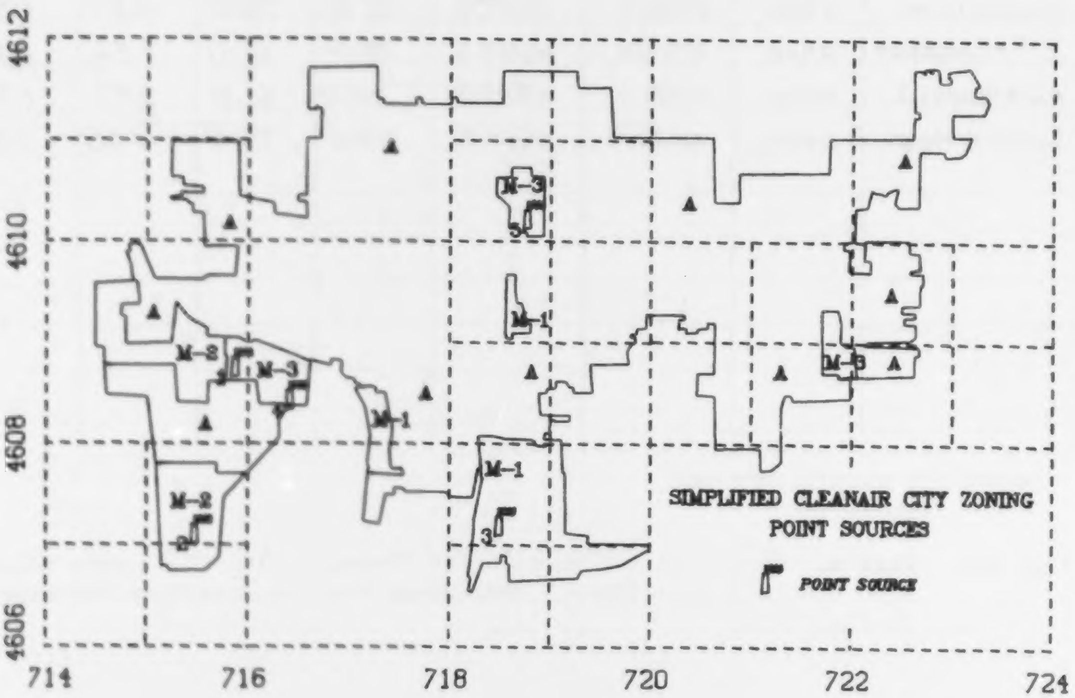

4612
4610
4608
4606
714
716
718
720
722
724
M-1
M-2
M-3
1
2
3
4
5
SIMPLIFIED CLEANAIR CITY ZONING
POINT SOURCES
POINT SOURCE

Fig. 137. Step 6: Completed Worksheet 6 and Point Source Map for Cleanair City [Note: Data from NEDS file.]

WORKSHEET 7 (FOR STEP 6) FILLED OUT BY:__________ DATE:______ PG___

EMISSION INVENTORY AREA SOURCES OF___

AREA SOURCE I.D. NUMBER FROM EMISSION INVENTORY (5 DIGITS)	UTM LOCATION (NORMALIZED) OF S.W. CORNER OF THE GRID SQUARE (km)		WIDTH OF THE GRID SQUARE (m)	EMISSION RATE (g/s)		ESTIMATED AVERAGE STACK HEIGHT (m)
	EASTING	NORTHING		SO_2	PART	
00143	710.55	4604.22	4000	18.06	22.24	7.5
00144	710.55	4608.22	4000	18.06	22.24	7.5
00165	714.55	4604.22	4000	35.07	58.20	10.0
00166	714.55	4608.22	4000	60.18	65.00	10.0
00187	718.66	4604.22	4000	30.01	35.06	10.0
00188	718.55	4608.22	4000	63.02	72.43	10.0
00301	722.55	4604.22	2000	9.13	14.27	5.0
00303	722.55	4608.22	2000	0.0	6.05	5.0
00305	722.55	4608.22	2000	4.75	13.70	5.0
00307	722.55	4610.22	2000	9.13	18.21	5.0

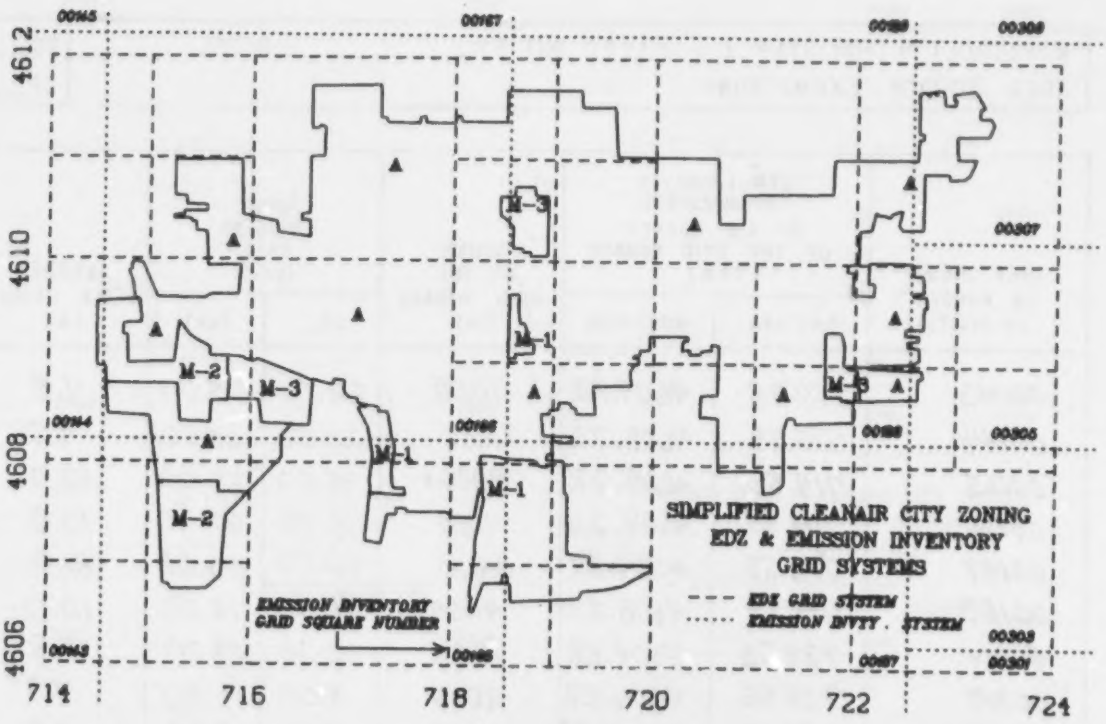

00145
00167
00189
00309
00307
00144
00166
00188
00305
00143
00165
00187
00303
00301
4612
4610
4608
4606
714
716
718
720
722
724
M-3
M-1
M-2
M-3
M-1
M-1
M-2
M-3
SIMPLIFIED CLEANAIR CITY ZONING
EDZ & EMISSION INVENTORY
GRID SYSTEMS
EDZ GRID SYSTEM
EMISSION INVTY. SYSTEM
EMISSION INVENTORY
GRID SQUARE NUMBER

Fig. 138. Step 6: Completed Worksheet 7 and Emission Inventory Grid System Map for Cleanair City [Note: Data from emission inventory; emission inventory grid squares mapped on top of EDZ grid system.]

WORKSHEET 8 (FOR STEP 6) FILLED OUT BY: ______________ DATE __________ PG ___ OF ___
EMISSION INVENTORY DATA FOR STEP 24

POINT SOURCE NAME	POINT SOURCE I.D. NUMBER (FROM WORKSHEET 6)	SIMPLIFIED LAND USE ZONING CLASS*	EMISSION RATE OF POINT SOURCE (A) IN g/s		LAND AREA OF POINT SOURCE (B) IN ha	EMISSION DENSITY (A ÷ B) IN (g/s)/ha	
			SO_2	PART		SO_2	PART
VESPUCCI	00001	M1	0.0679	0.0065	2.00	0.0340	0.0033
COLUMBUS	00002	M2	1.731	0.360	2.67	0.6483	0.1348
DRAKE-M.	00003	M3	2.332	0.0683	3.33	0.7003	0.0205
P. HENRY'S	00004	M3	7.090	1.324	4.67	1.5182	0.2835
COOK'S	00005	M3	2.762	0.2362	0.67	4.1224	0.3254

Fig. 139. Step 6: Completed Worksheet 8 for Cleanair City

WORKSHEET 9 (FOR STEP 7) FILLED OUT BY: ______________ DATE: __________ PG ___ OF ___
AREA SOURCE EXEMPTIONS

AREA SOURCE ID NUMBER* (5 DIGITS)	UTM LOCATION (NORMALIZED) OF S.W. CORNER OF THE GRID SQUARE (km)		WIDTH OF THE GRID SQUARE (m)	FUTURE EMISSION RATE (g/s)		AVERAGE STACK HEIGHT (m)
	EASTING	NORTHING		SO_2	PART	
00143	710.55	4604.22	4000	22.00	25.00	7.5
00144	710.55	4608.22	4000	20.00	23.50	7.5
00165	714.55	4604.22	4000	38.50	60.00	10.0
00166	714.55	4608.22	4000	55.00	60.00	10.0
00187	718.55	4604.22	4000	40.00	53.00	10.0
00188	718.55	4608.22	4000	60.00	72.50	10.0
00301	722.55	4604.22	2000	12.00	23.00	7.5
00303	722.55	4606.22	2000	5.00	10.00	7.5
00305	722.55	4608.22	2000	5.00	9.50	7.5
00307	722.55	4610.22	2000	10.00	20.00	7.5

Fig. 140. Step 7: Completed Worksheet 9 for Cleanair City

WORKSHEET 10 (FOR STEP 7) FILLED OUT BY: ______________________ DATE __________ PG ___
EXISTING POINT SOURCE EXEMPTIONS OF ___

NAME OF POINT SOURCE	POINT SOURCE ID NUMBER (FIVE DIGITS)	UTM LOCATION (NORMALIZED) IN km		FUTURE EMISSION RATE (g/s)		STACK HEIGHT (m)	STACK DIAMETER (m)	EXIT VELOCITY OF STACK GASES (m/s)	TEMP. OF STACK GASES (°C)
		EASTING	NORTHING	SO_2	PART				
10A↓									
CLEANAIR POWER + LITE	00010	721.8	4608.8	6.000	0.116	45.00	3.00	25.00	175.00
10B↓									
VESPUCCI	00001	715.9	4608.7	0.0679	0.0065	38.10	1.83	0.369	204.8
COLUMBUS	00002	715.5	4607.1	1.73	0.360	53.84	2.44	0.408	276.8
DRAKE-M	00003	715.5	4607.2	2.33	0.0683	44.50	2.18	3.881	204.1
P. HENRY'S	00004	716.4	4608.4	7.09	1.32	45.72	1.83	10.240	82.2
COOK'S	00005	718.8	4610.2	2.76	0.236	41.25	1.55	26.960	166.8

Fig. 141. Step 7: Completed Worksheet 10 for Cleanair City [In the test case, existing sources are treated as nonconforming uses and future power plants as exempt sources; Worksheet "10A" is completed accordingly. (If all existing sources were exempted, Worksheet "10B" would have been used.) Worksheet 10A is used in this test case.]

WORKSHEET 11 (FOR STEP 8) FILLED OUT BY: ______________________ DATE __________ PG ___
STACK HEIGHTS FOR AIR QUALITY RUNS OF ___

POINT SOURCE NAME	POINT SOURCE NUMBER (FROM WORKSHEET 6)	SIMPLIFIED LAND USE ZONING CLASS	STACK HEIGHT FROM WORKSHEET 6 (m)
VESPUCCI	00001	M1	38.10 (SO, M1 AVERAGE IS ALSO 38.10)
COLUMBUS	00002	M2	53.34 (SO, M2 AVERAGE IS 53.34)
DRAKE-MAGEL.	00003	M3	44.50 ($\frac{131.37}{3} = 43.79$ FOR THE M3 AVERAGE)
PRINCE HENRY'S	00004	M3	45.72
COOK'S	00005	M3	41.15

•AVERAGE STACK HEIGHT FOR ALL POINT SOURCES: 222.81 ÷ 5 = 44.56

Fig. 142. Step 8: Completed Worksheet 11 for Cleanair City [Note: Data from emission inventory; average stack heights are arithmetic means.]

LIGHT MANUFACTURING AIR QUALITY RUN DATA

```
LIGHT MANUFACTURING AIR QUALITY RUN OF CDM-QC FOR THE CLEANAIR CITY EXAMPLE
  A1  A2  P1  P200001 0000000050000600007000000000.00000000.0000001.00000001.0
000000 0000 00000000.000000000.0  SO2 PART
00075.0001.01000.011900.00395.00714.04606.                          010.091000.0
0004.001.00001.000011.90011.90011.90011.90011.90011.9099999.99999.
                                  (JOINT FREQUENCY FUNCTION)
                                          (BLANK CARD)
716.004608.0002000.00010000.0010000.038.10000035
718.004609.0001000.00010000.0010000.038.10000036
716.004606.0002000.00010000.0010000.038.10000048
718.004607.0001000.00010000.0010000.038.10000049
719.004607.0001000.00010000.0010000.038.10000050
718.004606.0001000.00010000.0010000.038.10000051
719.004606.0001000.00010000.0010000.038.10000052
                                          (BLANK CARD)
000714.5004610.8                                             00000300             0001
000715.5004610.5                                             00000300             0002
000714.0004606.0                                             00000300             0003
000717.0004609.7                                             00000300             0004
000718.0004609.4                                             00000300             0005
000718.4004607.3                                             00000300             0006
000720.9004611.8                                             00000300             0007
000721.1004607.0                                             00000300             0008
000723.7004610.9                                             00000300             0009
000722.8004608.2                                             00000300             0010
```

MEDIUM MANUFACTURING AIR QUALITY RUN DATA

```
MEDIUM MANUFACTURING RUN FOR CLEANAIR CITY--CDMQC APRIL 1,1978
  A1  A2  P1  P200001 0000000050000600007000000000.00000000.0000001.00000001.0
000000 0000 00000000.000000000.0  SO2 PART
00075.0001.01000.011900.00395.00714.04606.                          010.091000.0
0004.001.00001.000000.00000.00000.00000.00000.00000.0099999.99999.
                                  (JOINT FREQUENCY FUNCTION)
                                          (BLANK CARD)
714.004608.0002000.00010000.0010000.053.34000034
715.004607.0001000.00010000.0010000.053.34000045
715.004606.0001000.00010000.0010000.053.34000047
                                          (BLANK CARD)
                               (RECEPTOR CARDS FROM LIGHT MFG.RUN)
```

HEAVY MANUFACTURING AIR QUALITY RUN DATA

```
HEAVY MANUFACTURING AIR QUALITY RUN OF CDM-QC FOR THE CLEANAIR CITY EXAMPLE 4178
  A1  A2  P1  P200001 0000000050000600007000000000.00000000.0000001.00000001.0
000000 0000 00000000.000000000.0  SO2 PART
00075.0001.01000.011900.00395.00714.04606.                          010.091000.0
0004.001.00001.000006.21006.21006.21006.21006.21006.2199999.99999.
                                  (JOINT FREQUENCY FUNCTION)
                                          (BLANK CARD)
718.004610.0001000.00010000.0010000.043.79000031
714.004608.0002000.00010000.0010000.043.79000034
716.004608.0002000.00010000.0010000.043.79000035
721.004609.0001000.00010000.0010000.043.79000041
721.004608.0001000.00010000.0010000.043.79000043
                                          (BLANK CARD)
                               (RECEPTOR CARDS FROM LIGHT MFG.RUN)
```

Fig. 143. Step 9: Listing of Five CDMQC Data Decks for Cleanair City (continued on page 301)

CALIBRATION RUN DATA

```
CALIBRATION RUN FOR CLEANAIR CITY, APRIL 1,1978
  A1  A2  P1  P200001 0000000050000600007
000006 0003 00000000.000000000.0  SO2 PART
00350.0002.01000.011900.00395.710.554604.2                    010.092000.0
0004.001.00001.000005.44005.44005.44005.44005.44005.4499999.99999.
                            (JOINT FREQUENCY FUNCTION)
715.904608.70       000.0679000.0065038.1001.8300.36900204.61       00001
715.504607.10       001.7310000.3600053.3402.4400.40800276.85       00002
718.504607.20       002.3320000.0683044.5002.1803.88100204.11       00003
716.404608.40       007.0900001.3240045.7201.83010.240082.25        00004
718.804610.20       002.7620000.2362041.2501.55026.9600166.85       00005
                                   (BLANK CARD)
710.554604.2204000.00018.06013.34000007.50000143
710.554608.2204000.00018.06013.34000007.50000144
714.554604.2204000.00035.07034.92000010.00000165
714.554608.2204000.00060.18039.00000010.00000166
718.554604.2204000.00030.01021.04000010.00000187
718.554608.2204000.00063.02043.46000010.00000188
722.554604.2202000.00009.13010.96000005.00000301
722.554606.2202000.00000.0003.630000005.00000303
722.554608.2202000.00004.5708.220000005.00000305
722.554610.2202000.00009.13010.93000005.00000307
                                   (BLANK CARD)
0715.5004610.500              0039.054.000            00000 00                0001
0717.0004609.700              0048.000.000            00000300                0002
0718.5004609.400              0043.553.000            00000300                0003
0718.4004607.300              0035.052.000            00000300                0004
0721.1004607.000              0030.049.000            00000300                0005
0723.7004610.900              0042.056.000            00000300                0006
```

RHS RUN DATA

```
RIGHT HAND SIDE RUN FOR CLEANAIR CITY APRIL 1, 1978                  EXAMPLE
  A1  A2  P1  P200001 0000000050000600007000000000.00000000.0000001.00000001.0
000000 0000 00000000.000000000.0  SO2 PART
00350.0001.01000.011900.00395.710.554604.2                    010.091000.0
0004.001.00001.000004.01004.01004.01004.01004.01004.0199999.99999.
                            (JOINT FREQUENCY FUNCTION)
 721.84608.8        006.0000000.11600045.003.00025.000000175.0     00010
                                   (BLANK CARD)
710.554604.22004000.22.00    16.0000000007.500143
710.554608.22004000.20.00    15.0000000007.500144
714.554604.22004000.38.50    37.0000000010.000165
714.554608.22004000.55.00    36.0000000010.000166
718.554604.22004000.40.00    32.0000000010.000187
718.554608.22004000.60.00    40.0000000010.000188
722.554604.22002000.12.00    12.0000000005.000301
722.554606.22002000.5.00     05.0000000005.000303
722.554608.22002000.5.00     05.0000000005.000305
722.554610.22002000.10.00    12.0000000005.000307
                                   (BLANK CARD)
                        (RECEPTOR CARDS FROM LIGHT MFG.RUN)
```

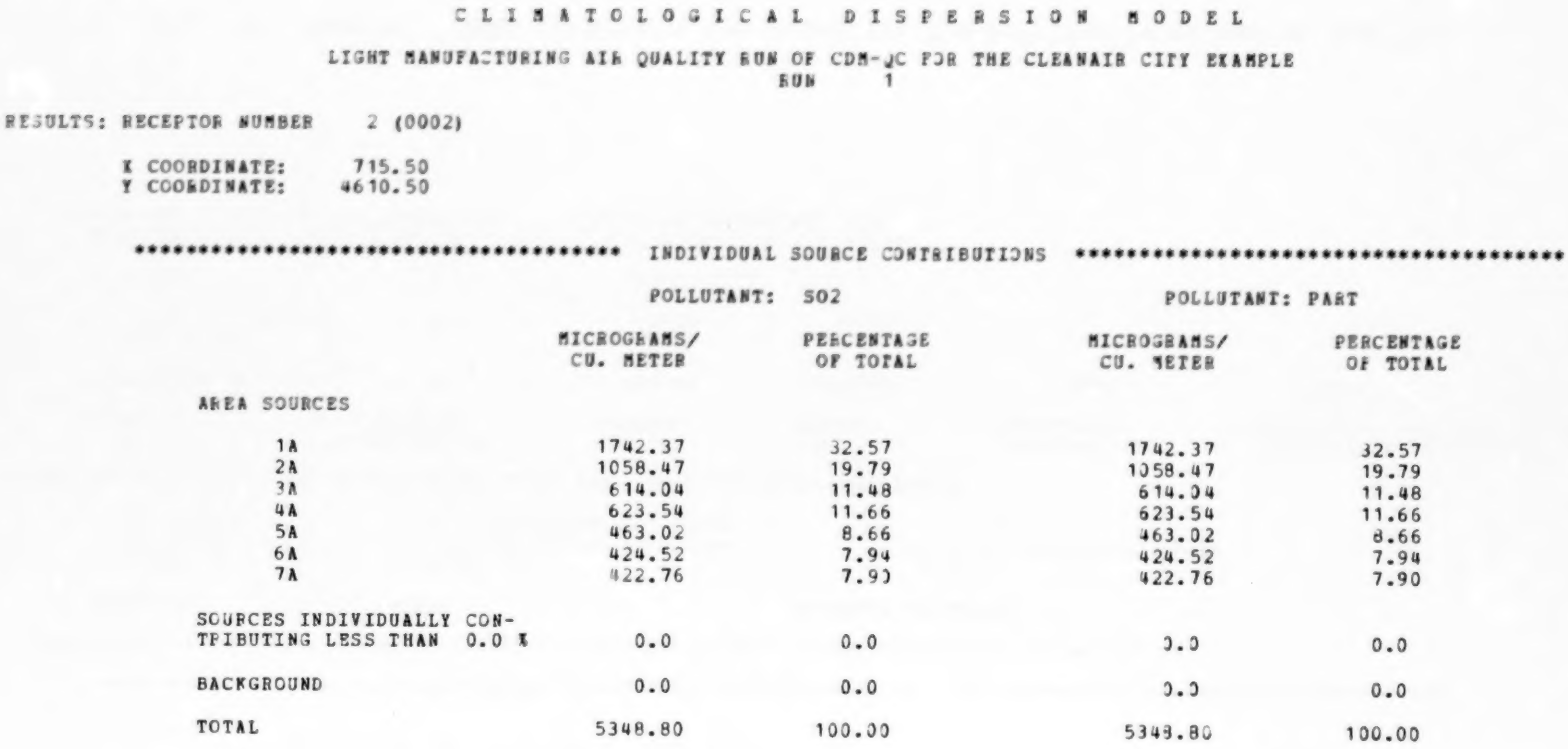
Fig. 143. Step 9: Listing of Five CDMQC Data Decks for Cleanair City (continued)

STEPS 10, 11, 12, and 13

In these four steps, the CDMQC and MPSX computer programs were acquired, installed on the computer, and tested.

The services of a programmer experienced in the use of dispersion models and linear programming are essential to the completion of these steps.

Because no printable results come from these steps, no results are shown here.



```
                    C L I M A T O L O G I C A L   D I S P E R S I O N   M O D E L

             LIGHT MANUFACTURING AIR QUALITY RUN OF CDM-QC FOR THE CLEANAIR CITY EXAMPLE
                                            RUN     1
RESULTS: RECEPTOR NUMBER    2 (0002)

         X COORDINATE:     715.50
         Y COORDINATE:    4610.50

     ************************************* INDIVIDUAL SOURCE CONTRIBUTIONS *************************************

                                       POLLUTANT:  SO2                          POLLUTANT: PART

                                  MICROGRAMS/        PERCENTAGE           MICROGRAMS/        PERCENTAGE
                                   CU. METER          OF TOTAL             CU. METER          OF TOTAL
         AREA SOURCES

              1A                   1742.37             32.57               1742.37             32.57
              2A                   1058.47             19.79               1058.47             19.79
              3A                    614.04             11.48                614.04             11.48
              4A                    623.54             11.66                623.54             11.66
              5A                    463.02              8.66                463.02              8.66
              6A                    424.52              7.94                424.52              7.94
              7A                    422.76              7.90                422.76              7.90

         SOURCES INDIVIDUALLY CON-
         TRIBUTING LESS THAN  0.0 %    0.0               0.0                  0.0               0.0

         BACKGROUND                    0.0               0.0                  0.0               0.0

         TOTAL                      5348.80            100.00               5348.80            100.00
```

Fig. 144. Step 14: CDMQC Light Manufacturing Air Quality Run Output for Cleanair City [The output of the three air quality runs is very similar; illustrated above is one relevant page from the light manufacturing run. Note that this output page is for only one receptor. The area sources are the EDZ grid squares, listed in the order in which they were input to the computer.]

```
                    C L I M A T O L O G I C A L   D I S P E R S I O N   M O D E L

              CALIBRATION RUN FOR CLEANAIR CITY, APRIL 1,1978
                                             RUN     1

 ***********************************  CALIBRATION PROCEDURE RESULTS:  SO2  ***********************************

REGRESSION COEFFICIENTS:  OBSERVED (MEASURED MINUS BACKGROUND) VERSUS CALCULATED CONCENTRATIONS

     PARAMETER               VALUE                          STANDARD DEVIATION

       SLOPE                  0.59
       INTERCEPT              7.01 MICROGRAMS/CU. METER        0.20
       BACKGROUND             0.0  MICROGRAMS/CU. METER       11.43 MICROGRAMS/CU. METER

ANALYSIS OF VARIANCE AND 5% CONFIDENCE LEVEL TEST FOR CORRELATION COEFFICIENT

     SOURCE              DEGREES OF      SUM OF       MEAN          MULTIPLE          CORRELATION COEFFICIENT
                          FREEDOM        SQUARES      SQUARES       CORRELATION      CALCULATED    5% CONF. LEVEL

       REGRESSION            1           138.48       138.48           0.67              0.82            0.81

       DEVIATIONS
       ABOUT REGRESSION      4            66.73        16.68

     TOTAL                   5           205.21

     AVERAGED OBSERVED CONCENTRATION:       39.58 MICROGRAMS/CU. METER
     AVERAGED CALCULATED CONCENTRATION:     55.48 MICROGRAMS/CU. METER
```

Fig. 145. Step 15: CDMQC Calibration Run Output for Cleanair City (continued on page 305)

```
**********************************  CALIBRATION PROCEDURE RESULTS: PART  **********************************
REGRESSION COEFFICIENTS:  OBSERVED (MEASURED MINUS BACKGROUND) VERSUS CALCULATED CONCENTRATIONS

  PARAMETER              VALUE                              STANDARD DEVIATION

    SLOPE                 0.28
    INTERCEPT            40.68 MICROGRAMS/CU. METER                   0.09
    BACKGROUND            0.0  MICROGRAMS/CU. METER                   3.71 MICROGRAMS/CU. METER

ANALYSIS OF VARIANCE AND 5% CONFIDENCE LEVEL TEST FOR CORRELATION COEFFICIENT

  SOURCE                DEGREES OF        SUM OF         MEAN          MULTIPLE              CORRELATION COEFFICIENT
                          FREEDOM         SQUARES        SQUARES       CORRELATION          CALCULATED     5% CONF. LEVEL

    REGRESSION              1              21.05          21.05            0.79                0.89              0.88

    DEVIATIONS
    ABOUT REGRESSION        3               5.76           1.92

    TOTAL                   4              26.80

  AVERAGED OBSERVED CONCENTRATION:         52.80 MICROGRAMS/CU. METER
  AVERAGED CALCULATED CONCENTRATION:       42.89 MICROGRAMS/CU. METER
```

Fig. 145. Step 15: CDMQC Calibration Run Output for Cleanair City (continued)
[The output page shown in this figure is the only one needed. The slope and intercept values are listed under PARAMETER and VALUE. Under the heading CORRELATION COEFFICIENT, if CALCULATED is greater than 5% CONF. LEVEL, CDMQC will use the data supplied by user to calculate regression coefficients; if the reverse is true, there are either (1) very few monitoring stations (in which case hand calculation of the slope and intercept may be needed), (2) the meteorological, emission inventory, or monitoring station data is poor, or (3) the model may not work well in your region. In the second case, the data should be checked and improved. In any of the three cases, the output's slope and intercept values may be used without modification if a confidence level of less than 5% is acceptable in the analysis.]

```
                    C L I M A T O L O G I C A L   D I S P E R S I O N   M O D E L

               RIGHT HAND SIDE RUN FOR CLEANAIR CITY APRIL 1, 1978              EXAMPLE
                                                   RUN     1
RESULTS: RECEPTOR NUMBER    5 (0005)

         X COORDINATE:     718.00
         Y COORDINATE:    4609.40

     ************************************** INDIVIDUAL SOURCE CONTRIBUTIONS **************************************

                                   POLLUTANT:  SO2                          POLLUTANT: PART

                              MICROGRAMS/       PERCENTAGE            MICROGRAMS/       PERCENTAGE
                              CU. METER         OF TOTAL              CU. METER         OF TOTAL
         POINT SOURCES

              1P                 0.03             0.05                   0.00              0.00

         AREA SOURCES

              1A                 0.69             1.14                   0.50              1.18
              2A                 1.24             2.05                   0.93              2.19
              3A                 4.44             7.31                   4.27             10.01
              4A                36.76            60.50                  24.06             56.39
              5A                 4.46             7.34                   3.57              8.36
              6A                11.55            19.01                   7.70             18.05
              7A                 0.62             1.01                   0.62              1.44
              8A                 0.33             0.55                   0.33              0.78
              9A                 0.32             0.53                   0.32              0.76
             10A                 0.29             0.48                   0.35              0.82

         SOURCES INDIVIDUALLY CON-
         TRIBUTING LESS THAN  0.0 %  0.0              0.0                    0.0               0.0

         BACKGROUND                  0.0              0.0                    0.0               0.0

         TOTAL                      60.75           100.00                  42.66            100.00
```

Fig. 146. Step 16: CDMQC Right-Hand-Side Run Output for Cleanair City [Note that output is for only one receptor. The area sources are the emission inventory grid squares, listed in the order in which they were input to the computer.]

STEPS 17, 18, 19, 20, and 21

The coefficient matrix drawn in Step 17 and completed in Steps 18-21 is shown in Fig. 148 on page 309. The methods described in the text were used to complete the matrix.

Worksheet 12 in Step 20 was not needed in this test case because the geometric mean particulate concentrations were assumed equal to arithmetic mean concentrations. Worksheet 13 is shown in Fig. 147 on page 308.

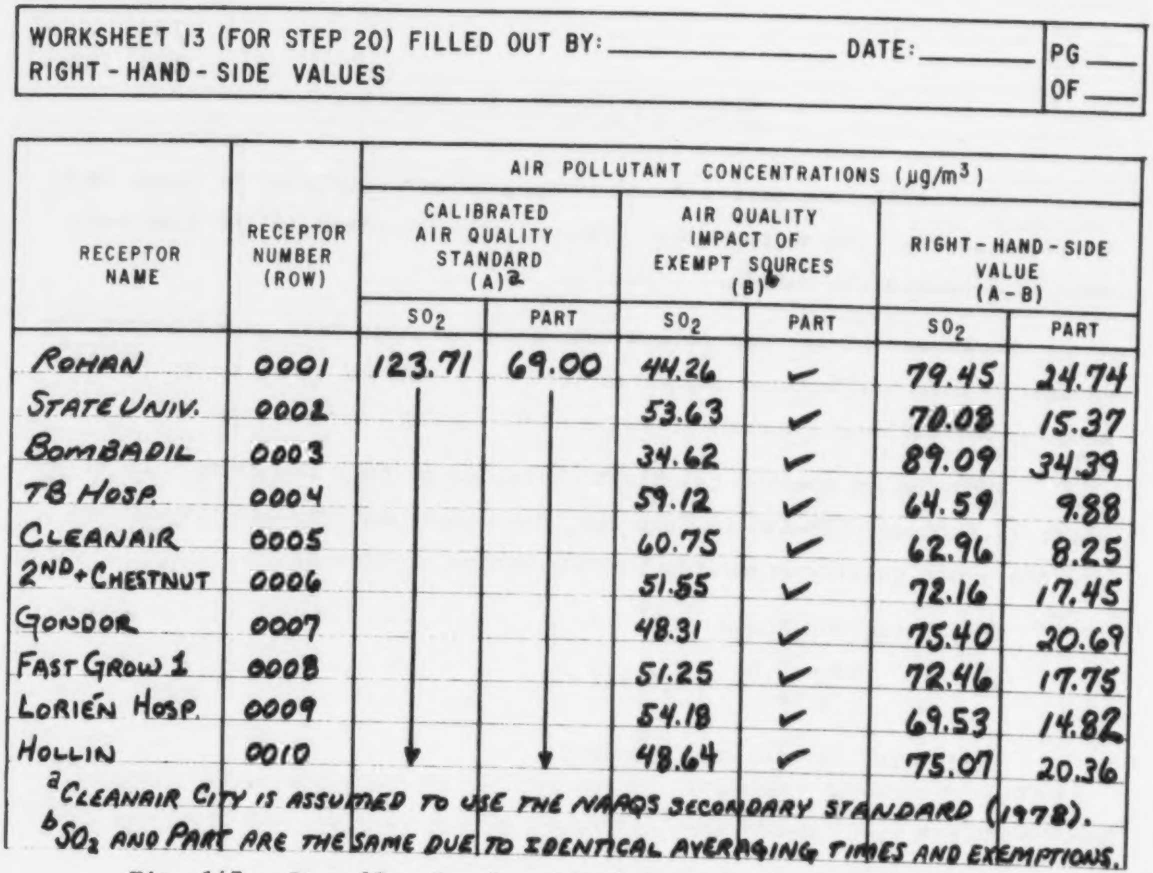
Shown below are the calculations needed to fill in Column A on Worksheet 13 (see pp. 158-160 in Step 20); these calculations use the current secondary air quality standards for SO_2 and particulates:

Calibrated SO_2 Standard

$$X = \frac{y-a}{b} = \frac{80 - 7.01}{0.59} = 123.712$$

Calibrated Particulate Standard

$$X = \frac{y-a}{b} = \frac{60 - 40.68}{0.28} = 69.000$$



WORKSHEET 13 (FOR STEP 20) FILLED OUT BY: __________ DATE: ________ PG ____
RIGHT-HAND-SIDE VALUES OF ____

RECEPTOR NAME	RECEPTOR NUMBER (ROW)	AIR POLLUTANT CONCENTRATIONS ($\mu g/m^3$)					
		CALIBRATED AIR QUALITY STANDARD (A)[a]		AIR QUALITY IMPACT OF EXEMPT SOURCES (B)[b]		RIGHT-HAND-SIDE VALUE (A-B)	
		SO_2	PART	SO_2	PART	SO_2	PART
ROHAN	0001	123.71	69.00	44.26	✓	79.45	24.74
STATE UNIV.	0002	↓	↓	53.63	✓	70.08	15.37
BOMBADIL	0003	↓	↓	34.62	✓	89.09	34.39
TB HOSP.	0004	↓	↓	59.12	✓	64.59	9.88
CLEANAIR	0005	↓	↓	60.75	✓	62.96	8.25
2ND + CHESTNUT	0006	↓	↓	51.55	✓	72.16	17.45
GONDOR	0007	↓	↓	48.31	✓	75.40	20.69
FAST GROW 1	0008	↓	↓	51.25	✓	72.46	17.75
LORIÉN HOSP.	0009	↓	↓	54.18	✓	69.53	14.82
HOLLIN	0010	↓	↓	48.64	✓	75.07	20.36

[a] CLEANAIR CITY IS ASSUMED TO USE THE NAAQS SECONDARY STANDARD (1978).

[b] SO_2 AND PART ARE THE SAME DUE TO IDENTICAL AVERAGING TIMES AND EXEMPTIONS.

Fig. 147. Step 20: Completed Worksheet 13 for Cleanair City

ROWS \ COLUMNS	COL0001	COL0002	COL0003	COL0004	COL0005	COL0006	COL0007	COL0008	COL0009	COL0010	COL0011	COL0012	COL0013	COL0014	COL0015	EQUATION TYPE	RHS FOR SO_2	RHS FOR PART
EXPLANATION OF COLUMNS	0031M3*	0034M2	0034M3	0035M1	0035M3	0036M1	0041M3	0043M3	0045M2	0047M2	0048M1	0049M1	0050M1	0051M1	0052M1			
OBJECTIVE FUNCTION	31.25	87.52	18.72	12.48	37.44	18.75	6.25	12.50	43.75	12.50	12.50	75.00	6.25	37.50	25.00	N		
ROW001	1.784	12.283	3.379	1.313	3.676	1.184	0.098	0.357	2.502	0.479	0.591	4.489	0.200	1.380	0.727	L	79.45	24.74
ROW002	2.451	10.949	3.227	2.174	5.850	1.985	0.236	0.393	4.238	1.054	0.768	5.841	0.289	1.592	1.057	L	70.08	15.37
ROW003	0.322	8.467	2.097	0.282	0.802	0.278	0.044	0.091	2.070	1.240	0.698	1.631	0.116	2.098	1.103	L	89.09	34.39
ROW004	2.480	8.178	2.158	5.884	11.767	4.579	0.256	0.635	1.813	0.337	1.418	9.866	0.553	2.410	1.441	L	64.59	9.88
ROW005	9.295	5.673	1.393	4.271	9.672	12.432	0.392	0.853	1.855	0.347	1.018	17.329	0.803	4.031	1.850	L	62.96	8.25
ROW006	6.094	4.009	0.954	1.336	3.666	6.512	0.151	0.340	3.587	0.665	2.788	84.241	1.606	18.765	7.926	L	72.16	17.45
ROW007	1.961	1.623	0.344	0.306	0.876	0.872	0.794	0.970	0.405	0.111	0.199	1.835	0.146	0.451	0.657	L	75.40	20.69
ROW008	0.983	1.992	0.493	0.587	1.439	0.827	1.363	3.235	0.993	0.284	0.723	9.903	1.286	3.541	4.350	L	72.46	17.75
ROW009	1.278	1.029	0.234	0.223	0.641	0.576	0.395	0.521	0.350	0.130	0.173	1.720	0.142	0.502	0.424	L	69.53	14.82
ROW010	1.172	1.785	0.423	0.408	1.168	0.866	1.517	3.033	0.577	0.212	0.319	4.205	0.400	1.324	1.069	L	75.07	20.36
SO_2 UPPER BOUNDS	4.143	0.6494	4.143	0.0348	4.143	0.0348	4.143	4.143	0.6494	0.6494	0.0348	0.0348	0.0348	0.0348	0.0348	LINEAR PROGRAMMING COEFFICIENT MATRIX FOR SO_2 AND PARTICULATES		
SO_2 LOWER BOUNDS	0.6896	0**	0.6996	0	0.6996	0	0.6996	0.6996	0	0	0	0	0	0	0			
PART UPPER BOUNDS	0.3543	0.1350	0.3543	0.0033	0.3543	0.0033	0.3543	0.3543	0.1350	0.1350	0.0033	0.0033	0.0033	0.0033	0.0033			
PART LOWER BOUNDS	0.0206	0	0.0206	0	0.0206	0	0.0206	0.0206	0	0	0	0	0	0	0			

*NOTATION FOR GRID SQUARE 0031, LAND USE CLASS M3.

**THE LOWER BOUND IN M1 AND M2 AREAS WERE SET EQUAL TO ZERO DUE TO THE SAMPLE SIZE OF ONLY ONE SOURCE IN EACH.

Fig. 148. Steps 18-21: Completed Coefficient Matrix for Cleanair City

```
NAME          EDZ2
ROWS
 N  OBJF
 I  ROW001
 I  ROW002
 I  ROW003
 I  ROW004
 I  ROW005
 I  ROW006
 I  ROW007
 I  ROW008
 I  ROW009
 I  ROW010
COLUMNS
    COL0001   OBJF         31.25000   ROW001         1.78400
    COL0001   ROW002        2.45100   ROW003          .32200
    COL0001   ROW004        2.48000   ROW005         9.29500
    COL0001   ROW006        6.09400   ROW007         1.96100
    COL0001   ROW008         .98300   ROW009         1.27800
    COL0001   ROW010        1.17200
    COL0002   OBJF         87.52000   ROW001        12.28300
    COL0002   ROW002       10.94900   ROW003         8.46700
    COL0002   ROW004        8.17800   ROW005         5.67300
    COL0002   ROW006        4.00900   ROW007         1.62300
    COL0002   ROW008        1.99200   ROW009         1.02900
    COL0002   ROW010        1.78500
    COL0003   OBJF         18.72000   ROW001         3.37900
    COL0003   ROW002        3.22700   ROW003         2.09700
    COL0003   ROW004        2.15800   ROW005         1.39300
    COL0003   ROW006         .95400   ROW007          .34400
    COL0003   ROW008         .49300   ROW009          .23400
    COL0003   ROW010         .42300
    COL0004   OBJF         12.48000   ROW001         1.31300
    COL0004   ROW002        2.17400   ROW003          .28200
    COL0004   ROW004        5.88400   ROW005         4.27100
    COL0004   ROW006        1.33600   ROW007          .30600
    COL0004   ROW008         .58700   ROW009          .22300
    COL0004   ROW010         .40800
    COL0005   OBJF         37.44000   ROW001         3.67600
    COL0005   ROW002        5.85000   ROW003          .80200
    COL0005   ROW004       11.76700   ROW005         9.67200
    COL0005   ROW006        3.66600   ROW007          .87600
    COL0005   ROW008        1.43900   ROW009          .64100
    COL0005   ROW010        1.16800
    COL0006   OBJF         18.75000   ROW001         1.18400
    COL0006   ROW002        1.98500   ROW003          .27800
    COL0006   ROW004        4.57900   ROW005        12.43200
    COL0006   ROW006        6.51200   ROW007          .87200
    COL0006   ROW008         .82700   ROW009          .57600
    COL0006   ROW010         .86600
    COL0007   OBJF          6.25000   ROW001          .09800
```

Fig. 149. Step 22: Listing of MPSX Data Deck for Cleanair City (continued on pages 311 and 312)

```
COL0007   ROW002        .23600   ROW003          .04400
COL0007   ROW004        .25600   ROW005          .39200
COL0007   ROW006        .15100   ROW007          .79400
COL0007   ROW008       1.36300   ROW009          .39500
COL0007   ROW010       1.51700
COL0008   OBJF        12.50000   ROW001          .35700
COL0008   ROW002        .39300   ROW003          .09100
COL0008   ROW004        .63500   ROW005          .85300
COL0008   ROW006        .34000   ROW007          .97000
COL0008   ROW008       3.23500   ROW009          .52100
COL0008   ROW010       3.03300
COL0009   OBJF        43.75000   ROW001         2.50200
COL0009   ROW002       4.23800   ROW003         2.07000
COL0009   ROW004       1.81300   ROW005         1.85500
COL0009   ROW006       3.58700   ROW007          .40500
COL0009   ROW008        .99300   ROW009          .35000
COL0009   ROW010        .57700
COL0010   OBJF        12.50000   ROW001          .47900
COL0010   ROW002       1.05400   ROW003         1.24000
COL0010   ROW004        .33700   ROW005          .34700
COL0010   ROW006        .66500   ROW007          .11100
COL0010   ROW008        .28400   ROW009          .13000
COL0010   ROW010        .21200
COL0011   OBJF        12.50000   ROW001          .59100
COL0011   ROW002        .76800   ROW003          .69800
COL0011   ROW004       1.41800   ROW005         1.01800
COL0011   ROW006       2.78800   ROW007          .19900
COL0011   ROW008        .72300   ROW009          .17300
COL0011   ROW010        .31900
COL0012   OBJF        75.00000   ROW001         4.48900
COL0012   ROW002       5.84100   ROW003         1.63100
COL0012   ROW004       9.86600   ROW005        17.32900
COL0012   ROW006      84.24100   ROW007         1.83500
COL0012   ROW008       9.90300   ROW009         1.72000
COL0012   ROW010       4.20500
COL0013   OBJF         6.25000   ROW001          .20000
COL0013   ROW002        .28900   ROW003          .11600
COL0013   ROW004        .53300   ROW005          .80300
COL0013   ROW006       1.60600   ROW007          .14600
COL0013   ROW008       1.28600   ROW009          .14200
COL0013   ROW010        .40000
COL0014   OBJF        37.50000   ROW001         1.38000
COL0014   ROW002       1.59200   ROW003         2.09800
COL0014   ROW004       2.41000   ROW005         4.03100
COL0014   ROW006      18.76500   ROW007          .45100
COL0014   ROW008       3.54100   ROW009          .50200
COL0014   ROW010       1.32400
COL0015   OBJF        25.00000   ROW001          .72700
COL0015   ROW002       1.05700   ROW003         1.10300
COL0015   ROW004       1.44100   ROW005         1.85000
COL0015   ROW006       7.92600   ROW007          .65700
COL0015   ROW008       4.35000   ROW009          .42400
COL0015   ROW010       1.06900
```

Fig. 149. Step 22: Listing of MPSX Data Deck for Cleanair City (continued)

```
RHS
     SO2X       ROW001        79.45000    ROW002        70.08000
     SO2X       ROW003        89.09000    ROW004        64.59000
     SO2X       ROW005        62.96000    ROW006        72.16000
     SO2X       ROW007        75.40000    ROW008        72.46000
     SO2X       ROW009        69.53000    ROW010        75.07000
     PART       ROW001        24.74000    ROW002        15.37000
     PART       ROW003        34.39000    ROW004         9.88000
     PART       ROW005         8.25000    ROW006        17.45000
     PART       ROW007        20.69000    ROW008        17.75000
     PART       ROW009        14.82000    ROW010        20.36000
BOUNDS
 LO SO2X1.50   COL0001          .69960
 UP SO2X1.50   COL0001         4.14300
 UP SO2X1.50   COL0002          .64935
 LO SO2X1.50   COL0003          .69960
 UP SO2X1.50   COL0003         4.14300
 UP SO2X1.50   COL0004          .03484
 LO SO2X1.50   COL0005          .69960
 UP SO2X1.50   COL0005         4.14300
 UP SO2X1.50   COL0006          .03484
 LO SO2X1.50   COL0007          .69960
 UP SO2X1.50   COL0007         4.14300
 LO SO2X1.50   COL0008          .69960
 UP SO2X1.50   COL0008         4.14300
 UP SO2X1.50   COL0009          .64935
 UP SO2X1.50   COL0010          .64935
 UP SO2X1.50   COL0011          .03484
 UP SO2X1.50   COL0012          .03484
 UP SO2X1.50   COL0013          .03484
 UP SO2X1.50   COL0014          .03484
 UP SO2X1.50   COL0015          .03484
 LO PART1.50   COL0001          .02055
 UP PART1.50   COL0001          .35430
 UP PART1.50   COL0002          .13500
 LO PART1.50   COL0003          .02055
 UP PART1.50   COL0003          .35430
 UP PART1.50   COL0004          .00330
 LO PART1.50   COL0005          .02055
 UP PART1.50   COL0005          .35430
 UP PART1.50   COL0006          .00330
 LO PART1.50   COL0007          .02055
 UP PART1.50   COL0007          .35430
 LO PART1.50   COL0008          .02055
 UP PART1.50   COL0008          .35430
 UP PART1.50   COL0009          .13500
 UP PART1.50   COL0010          .13500
 UP PART1.50   COL0011          .00330
 UP PART1.50   COL0012          .00330
 UP PART1.50   COL0013          .00330
 UP PART1.50   COL0014          .00330
 UP PART1.50   COL0015          .00330
ENDATA
```

Fig. 149. Step 22: Listing of MPSX Data Deck for Cleanair City (continued)

```
                         EXECUTOR.    MPS/360 V2-M8

                SOLUTION   (OPTIMAL)

                TIME =   0.05 MINS. ITERATION NUMBER =     4

                        ...NAME...     ...ACTIVITY...       DEFINED AS

                        FUNCTIONAL        426.21623         OBJF
                        RESTRAINTS                          SO2X
                        BOUNDS....                          SO2X1.50



           EXECUTOR.    MPS/360 V2-M8

SECTION 2 - COLUMNS

NUMBER  .COLUMN.  AT  ...ACTIVITY...  ..INPUT COST..  ..LOWER LIMIT.  ..UPPER LIMIT.  .REDUCED COST.

    12  COL0001   BS         1.28143        31.25000          .69960         4.14300          .
    13  COL0002   UL          .64935        87.52000         .                .64935        64.87615
    14  COL0003   UL         4.14300        18.72000          .69960         4.14300        13.07950
    15  COL0004   LL          .             12.48000         .                .03484         4.42150-
    16  COL0005   BS         3.52916        37.44000          .69960         4.14300          .
    17  COL0006   LL          .             18.75000         .                .03484        23.72291-
    18  COL0007   UL         4.14300         6.25000          .69960         4.14300         4.85095
    19  COL0008   UL         4.14300        12.50000          .69960         4.14300         9.41388
    20  COL0009   UL          .64935        43.75000         .                .64935        36.80716
    21  COL0010   UL          .64935        12.50000         .                .64935        11.20241
    22  COL0011   UL          .03484        12.50000         .                .03484         8.46317
    23  COL0012   UL          .03484        75.00000         .                .03484        13.93036
    24  COL0013   UL          .03484         6.25000         .                .03484         3.37949
    25  COL0014   UL          .03484        37.50000         .                .03484        23.23260
    26  COL0015   UL          .03484        25.00000         .                .03484        18.27260
```

Fig. 150. Step 23: MPSX Output for Sulfur Dioxide for Cleanair City

```
                    EXECUTOR.    MPS/360 V2-M8

          SOLUTION    (OPTIMAL)

          TIME =    0.06 MINS. ITERATICN NUMBER =      4

                ...NAME...    ...ACTIVITY...       DEFINED AS

                FUNCTIONAL         55.68668        OBJF
                RESTRAINTS                         PART
                BOUNDS....                         PART1.50




          EXECUTOR.    MPS/360 V2-M8

SECTICN 2 - COLUMNS

NUMBER  .COLUMN.  AT  ...ACTIVITY...  ..INPUT COST..  ..LOWER LIMIT.  ..UPPER LIMIT.  .REDUCED COST.

    12  COL0001   BS        .29509        31.25000          .02055          .35430              .
    13  COL0002   UL        .13500        87.52000            .             .13500        68.44725
    14  COL0003   UL        .35430        18.72000          .02055          .35430        14.03670
    15  COL0004   LL          .           12.48000            .             .00330         1.87920-
    16  COL0005   UL        .35430        37.44000          .02055          .35430         4.92252
    17  COL0006   LL          .           18.75000            .             .00330        23.04666-
    18  COL0007   UL        .35430         6.25000          .02055          .35430         4.93209
    19  COL0008   UL        .35430        12.50000          .02055          .35430         9.63219
    20  COL0009   UL        .13500        43.75000            .             .13500        37.51345
    21  COL0010   UL        .13500        12.50000            .             .13500        11.33338
    22  COL0011   UL        .00330        12.50000            .             .00330         9.07746
    23  COL0012   UL        .00330        75.00000            .             .00330        16.73951
    24  COL0013   UL        .00330         6.25000            .             .00330         3.55030
    25  COL0014   UL        .00330        37.50000            .             .00330        23.94769
    26  COL0015   UL        .00330        25.00000            .             .00330        18.78026
```

Fig. 151. Step 23: MPSX Output for Particulates for Cleanair City

WORKSHEET 14 (FOR STEP 24) FILLED OUT BY: ______ DATE: ____	PG ___
FINDING THE POTENTIAL EMISSIONS OF EDZ SOURCES PER km^2	OF ___

COLUMN NUMBERS FROM LP OUTPUT OR MATRIX	EXPLANATION OF COLUMNS[a]	ACTIVITIES X INPUT COST = EMISSIONS PER EDZ GRID SQUARE PER LAND USE CLASS (g/s)[b]		EMISSIONS OF FUTURE EDZ SOURCES LOCATED IN EACH EDZ GRID SQUARE IF FUTURE CONSTRUCTION USES ALL OF THE EDL ALLOCATED (g/s)[c]	
		SO_2	PART	SO_2	PART
0001	0031 m3	40.045	9.222	40.045	9.222
0002	0034 m2	56.831	11.815	134.388	18.447
0003	0034 m3	77.557	6.632		
0004	0035 m1	0	0	132.132	13.265
0005	0035 m3	132.132	13.265		
0006	0036 m1	0	0	0.0	0.0
0007	0041 m3	25.892	2.219	25.892	2.219
0008	0043 m3	51.788	4.429	51.788	4.429
0009	0045 m2	28.409	5.906	28.409	5.906
0010	0047 m2	8.117	1.688	8.117	1.688
0011	0048 M1	0.436	0.0412	0.436	0.0412
0012	0049 M1	2.613	0.248	2.613	0.248
0013	0050 M1	0.218	0.206	0.218	0.206
0014	0051 M1	1.306	0.124	1.306	0.124
0015	0052 M1	0.871	0.0825	0.871	0.0825

[a] From LP matrix. The "explanation" for each column number consists of an EDZ grid square number and a land use class.

[b] From LP output; see text.

[c] The number of entries in this column will equal the number of EDZ grid squares included in the LP matrix.

Fig. 152. Step 24: Completed Worksheet 14 for Cleanair City

Emission Inventory Grid Square Number (A)	EDZ Grid Square Number (B)	Fraction of A Covered by B (C)	Emission Rate (g/s) of A (D)		Emission Rate (g/s) of B (equals C × D)	
			SO2	PART	SO2	PART
00143	0046	0.0344	18.06	22.24	0.621	0.765
	0044	0.0344			0.621	0.765
	0034	0.00756			0.137	0.168
00144	0034	0.0500	18.06	22.24	0.903	1.112
	0026	0.0344			0.621	0.765
	0024	0.0344			0.621	0.765
00165	0046	0.0281	35.07	58.20	0.985	1.635
	0044	0.0281			0.985	1.635
	0034	0.0200			0.701	1.164
	0047	0.0625			2.192	3.638
	0045	0.0625			2.192	3.638
	0048	0.250			8.768	14.55
	0035	0.0275			0.964	1.601
	0050	0.0344			1.206	2.002
	0049	0.0344			1.206	2.002
	0038	0.00756			0.265	0.440
00166	0034	0.1612	60.18	65.00	9.701	10.478
	0026	0.0281			1.691	1.827
	0024	0.0281			1.691	1.827
	0027	0.0625			3.761	4.063
	0025	0.0625			3.761	4.063
	0035	0.195			11.735	12.675
	0028	0.250			15.045	16.25
	0038	0.0268			1.613	1.74
	0036	0.0344			2.070	2.236
	0031	0.0344			2.070	2.236
	0029	0.0344			2.070	2.236
00187	0050	0.0281	30.01	35.06	0.843	0.985
	0049	0.0281			0.843	0.985
	0038	0.00619			0.186	0.217
	0052	0.0625			1.876	2.191
	0051	0.0625			1.876	2.191
	0039	0.0138			0.414	0.484
00187 (contd)	0053	0.250	30.01	35.06	7.503	8.765
	0042	0.0138			0.414	0.484
	0043	0.0138			0.414	0.484
	0074	0.0688			2.065	2.412
	0071	0.00756			0.227	0.265
00188	0038	0.0219	63.02	72.43	1.380	1.586
	0036	0.0281			1.771	2.035
	0031	0.0281			1.771	2.035
	0029	0.0281			1.771	2.035
	0039	0.0487			3.069	3.527
	0037	0.0625			3.939	4.527
	0032	0.0625			3.939	4.527
	0030	0.0625			3.939	4.527
	0042	0.0487			3.069	3.527
	0040	0.0625			3.949	4.527
	0033	0.250			15.755	18.108
	0043	0.0487			3.069	3.527
	0041	0.0625			3.939	4.537
	0071	0.0268			1.689	1.941
	0069	0.0344			2.168	2.492
	0066	0.0688			4.336	4.983
00301	0074	0.0800	9.13	18.27	0.730	1.462
00303	0074	0.6448	0	6.05	0	3.901
	0071	0.0876			0	0.530
	0072	0.195			0	1.178
00305	0071	0.0876	4.57	13.70	0.400	1.200
	0069	0.1124			0.514	1.540
	0072	0.195			0.891	2.672
	0070	0.250			1.143	3.425
	0066	0.0800			0.366	1.096
00307	0066	0.645	9.13	18.21	5.889	11.745

Fig. 153a. Step 24: Reallocating Area Source Emissions from Emission Inventory to EDZ Grid System for Cleanair City - Part 1 [This is the first set of calculations needed to complete Column B of Worksheet 15; see pages 188-190 in Step 24.]

EDZ Grid Square Number (A)	Sum of All Emissions from Each Emission Inventory Grid Square Containing Parts of A	
	SO2	PART
0024	2.312	2.592
0025	3.761	4.063
0026	2.312	2.592
0027	3.761	4.063
0028	15.045	16.25
0029	3.841	4.271
0030	3.939	4.527
0031	3.841	4.271
0032	3.939	4.527
0033	15.755	18.108
0034	11.442	12.922
0035	12.699	14.276
0036	3.841	4.271
0037	3.939	4.527
0038	3.444	3.983
0039	3.483	4.011
0040	3.939	4.527
0041	3.939	4.527
0042	3.483	4.011
0043	3.483	4.011
0044	1.606	2.40
0045	2.192	3.638
0046	1.606	2.40
0047	2.192	3.638
0048	8.768	14.55
0049	2.049	2.987
0050	2.049	2.987
0051	1.876	2.191
0053	1.876	2.191
0066	10.591	17.824
0069	2.682	4.032
0070	1.143	3.425
0071	2.316	3.936
0072	0.891	3.85
0074	2.795	7.775

Fig. 153b. Step 24: Reallocating Area Source Emissions from Emission Inventory to EDZ Grid System for Cleanair City - Part 2 [This is the second set of calculations needed to complete Column B of Worksheet 15.]

WORKSHEET 15 (FOR STEP 24) FILLED OUT BY: ______________ DATE ______ PG ___ OF ___

COMPARISON OF TOTAL EMISSIONS WITHIN EACH SQUARE KILOMETER

EDZ GRID SQUARE NUMBERS	A: EMISSIONS OF EXEMPT POINT SOURCES LOCATED IN EACH EDZ GRID SQUARE (g/s)[a]		B: EMISSIONS OF EXEMPT AREA SOURCES LOCATED IN EACH EDZ GRID SQUARE (g/s)[b]		C: EMISSIONS OF FUTURE EDZ SOURCES LOCATED IN EACH EDZ GRID SQUARE IF FUTURE CONSTRUCTION USES ALL OF THE EDL ALLOCATED (g/s)[c]		D: TOTAL POTENTIAL EMISSIONS FROM EACH EDZ GRID SQUARE (g/s) D = A + B + C		E: AREA OF EDZ GRID SQUARE (km²)	F: TOTAL EMISSIONS FROM EACH km² F = D ÷ E	
	SO_2	PART	SO_2	PART	SO_2	PART	SO_2	PART		SO_2	PART
00024	0	0	2.312	2.592	0	0	✓[d]	✓[d]	1	2.312	2.592
00025			3.761	4.063	0	0	✓	✓	1	3.761	4.063
26			2.312	2.592	0	0	✓	✓	1	2.312	2.592
27			3.761	4.063	0	0	✓	✓	1	3.761	4.063
28			15.045	16.250	0	0	✓	✓	4	3.761	4.063
29			3.841	4.271	0	0	✓	✓	1	3.841	4.271
30			3.939	4.527	0	0	✓	✓	1	3.939	4.527
31			3.841	4.271	40.045	9.222	43.886	13.493	1	43.886	13.493
32			3.939	4.527	0	0	✓	✓	1	3.939	4.527
33			15.755	18.108	0	0	✓	✓	4	3.939	4.527
34			11.442	12.922	134.388	18.447	145.830	31.369	4	36.458	7.842
35			12.699	14.276	132.582	13.265	145.279	27.541	4	36.320	6.885
36			3.841	4.271	00.000	0	✓	✓	1	3.841	4.271
37			3.939	4.527	0	0	✓	✓	1	3.939	4.527
38			3.444	3.983	0	0	✓	✓	1	3.444	3.983
39			3.483	4.011	0	0	✓	✓	1	3.483	4.011
40			3.939	4.527	0	0	✓	✓	1	3.989	4.527
41			3.939	4.527	25.894	2.214	29.833	6.741	1	29.833	6.741
42	↓	↓	3.483	4.011	0	0	✓	✓	1	3.483	4.011
43	6.000	0.116	3.483	4.011	51.788	4.429	55.271	8.440	1	55.271	8.440
44	0	0	1.606	2.400	0	0	✓	✓	1	1.606	2.400
45			2.192	3.638	28.409	5.906	30.601	9.544	1	30.601	9.544
46			1.606	2.400	0	0	✓	✓	1	1.606	2.400
47			2.192	3.638	8.117	1.688	10.309	5.326	1	10.309	5.326
48			8.768	14.550	0.436	0.0412	9.204	14.591	4	2.301	3.648
49			2.049	2.987	2.613	0.248	4.662	3.235	1	4.662	3.235
50			2.049	2.987	0.218	0.0206	2.267	3.008	1	2.267	3.008
51			1.876	2.191	1.306	0.124	3.182	2.315	1	3.182	2.315
52			1.876	2.191	0.871	0.0825	2.747	2.274	1	2.747	2.274
53			7.503	8.765	0	0	✓	✓	4	1.876	2.191
68			10.591	17.824	0	0	✓	✓	4	2.648	4.456
69			2.682	4.032	0	0	✓	✓	1	2.682	4.032
70			1.143	3.425	0	0	✓	✓	1	1.143	3.425
71			2.316	3.936	0	0	✓	✓	1	2.316	3.936
72			0.891	3.850	0	0	✓	✓	1	0.891	3.850
74	↓	↓	2.795	7.775	0	0	✓	✓	4	0.699	1.944

[a] Exempt sources from Step 7 are mapped onto the general regional map and the emissions of the exempt sources are summed for each EDZ grid square. The results are placed in Column B. Use the gridded zoning maps from Step 2 to assist in locating the exempt sources.

[b] From the emission inventory (Step 6). Emissions from each emission inventory grid square are reallocated to the appropriate km² grids.

[c] From final column of Worksheet 14.

[d] Checks (✓) indicate that the entry in Column D equals that in Column B.

Fig. 154. Step 24: Completed Worksheet 15 for Cleanair City

STEP 24: EMISSIONS MAPS

The total potential emissions (TPE) map for SO_2* (Fig. 155) shows a relatively low TPE area with a number of taller islands. With the exception of the squares with M1 zones, these islands occur in squares containing manufacturing lands. For most of the squares, the high TPE are probably caused by the much higher stack heights expected in the manufacturing areas. In a region larger than Cleanair, the effects of the taller stacks should be lessened due to increased distances from sources to receptors.

The particulate TPE map** (Fig. 156) shows much less variation than that for SO_2. This is primarily due to the difference in the upper bounds. Again, manufacturing zoning correlated with higher TPE, again suggesting the stack height factor.

The emission density limits for each zoning district, shown in Figs. 157-162, are per hectare emission limits in terms of the grams-per-second emission rates of SO_2 and particulates.

Sulfur Dioxide EDLs. The light manufacturing EDLs were set at either their upper bound or at zero, their lower bound. The center of Cleanair, which had the highest reported concentration of SO_2 in the monitoring station data, is protected from further pollution increases by the zero EDL. All medium manufacturing EDLs were set at their upper limit. For heavy manufacturing, the EDLs were set at the upper bound and between the upper and lower bound. The M3 area just north of downtown has the lowest EDL due to its nearness to the sensitive downtown receptor. The striking feature about this map is the change in the EDL in the M3 area spanning the boundary of grid squares 34 and 35. The upper bound was too high to allow it on both sides of the line without violating air quality standards. In Cleanair City, no borderline adjustments will be made (such as those suggested in Step 24) because the small size of the region would probably cause any changes in EDLs to cause large changes in air quality.

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*Note that grid square 34 was split into four parts (using Worksheet 16 data) to better illustrate the high total potential emissions in the M3 area.

**Here grid square 34 was not divided; if it had been, the M3 corner would be shaded like square 33, and the rest like 35.

Particulate EDLs. The light and medium manufacturing EDLs for particulates are basically the same as those for SO_2. No heavy manufacturing particulate EDLs were set at the lower bound; again, the downtown receptor is protected by lower nearby EDLs. The EDL split between grid squares 34 and 35 that occurred in the SO_2 map is absent from the particulate map. The particulate upper bound was low enough that it was appropriate for both grid squares.

STEP 25

The EDLs on the maps in Figs. 157-162 would be transferred to the EDZ implementing authority for passage and administration.

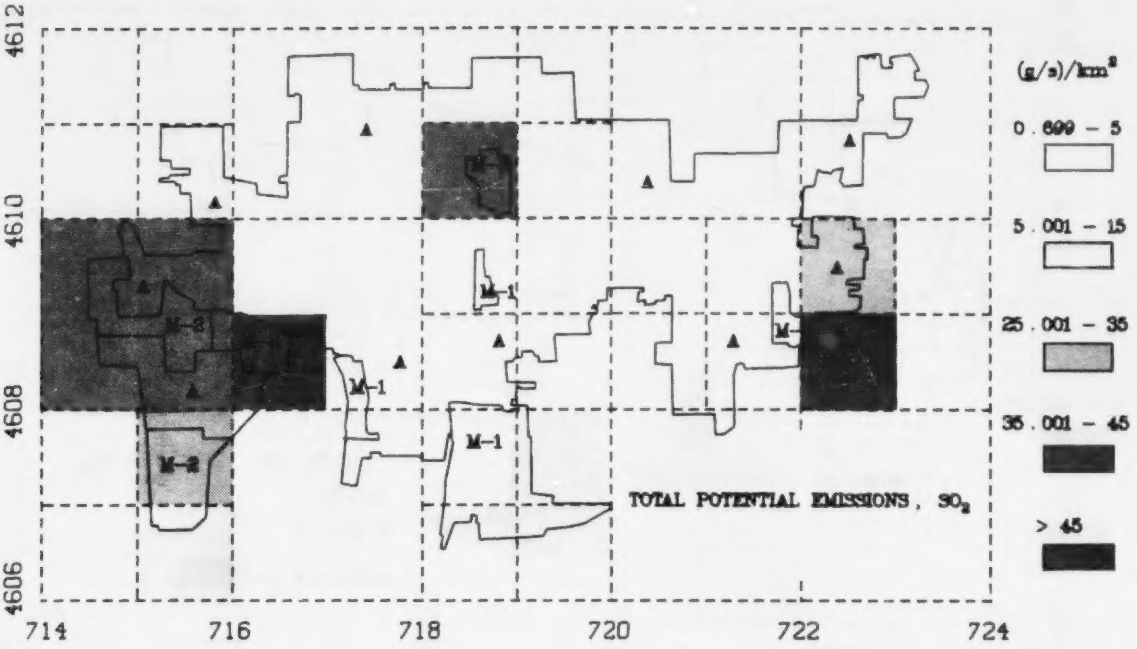
4612
4610
4608
4606
714
716
718
720
722
724
M-1
M-2
M-1
M-1
M-1
M-2
M-
TOTAL POTENTIAL EMISSIONS, SO_2
$(g/s)/km^2$
0.699 - 5
5.001 - 15
25.001 - 35
35.001 - 45
> 45

Fig. 155. Step 24: Map of Total Potential SO_2 Emissions for Cleanair City

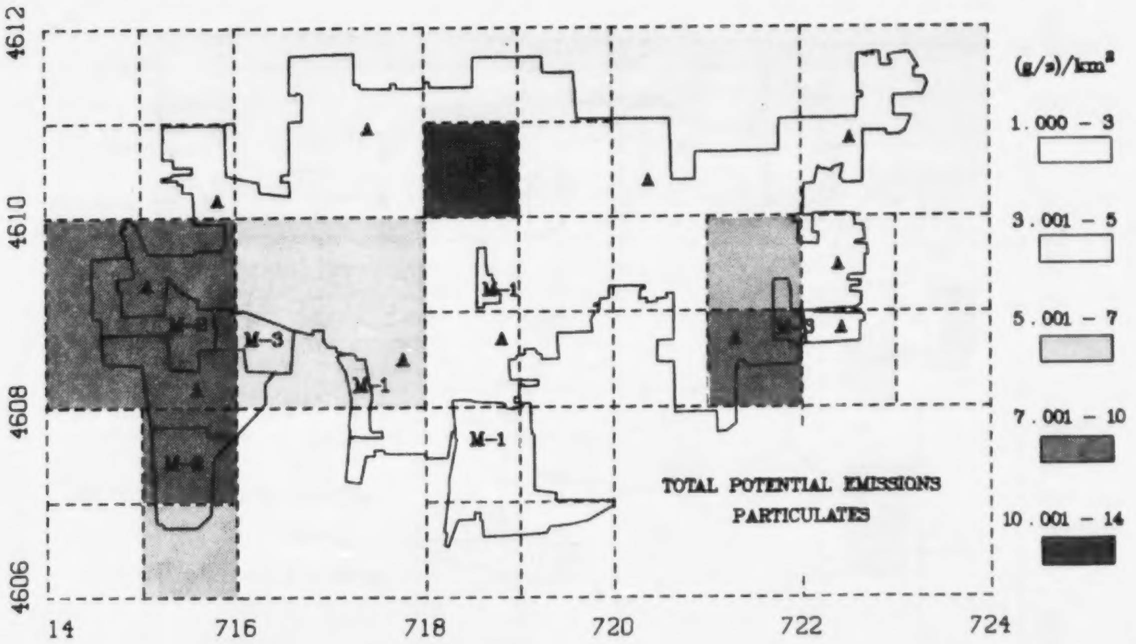
4612
4610
4608
4606
14
716
718
720
722
724
M-2
M-3
M-1
M-1
M-1
M-2
M-3
TOTAL POTENTIAL EMISSIONS
PARTICULATES
$(g/s)/km^2$
1.000 - 3
3.001 - 5
5.001 - 7
7.001 - 10
10.001 - 14

Fig. 156. Step 24: Map of Total Potential Particulate Emissions for Cleanair City

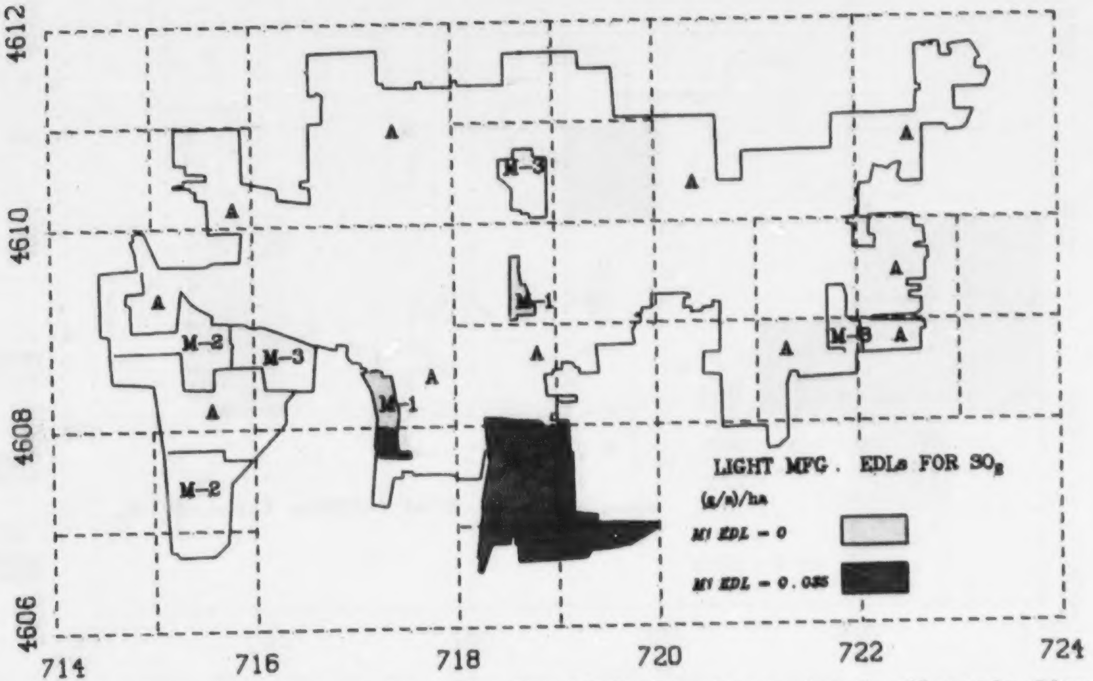
4612
4610
4608
4606
714
716
718
720
722
724
A
M-3
M-1
M-2
M-3
M-1
M-2
M-3
LIGHT MFG. EDLs FOR SO$_2$
(g/s)/ha
M1 EDL = 0
M1 EDL = 0.035

Fig. 157. Step 24: Map of SO₂ EDLs for Light Manufacturing in Cleanair City

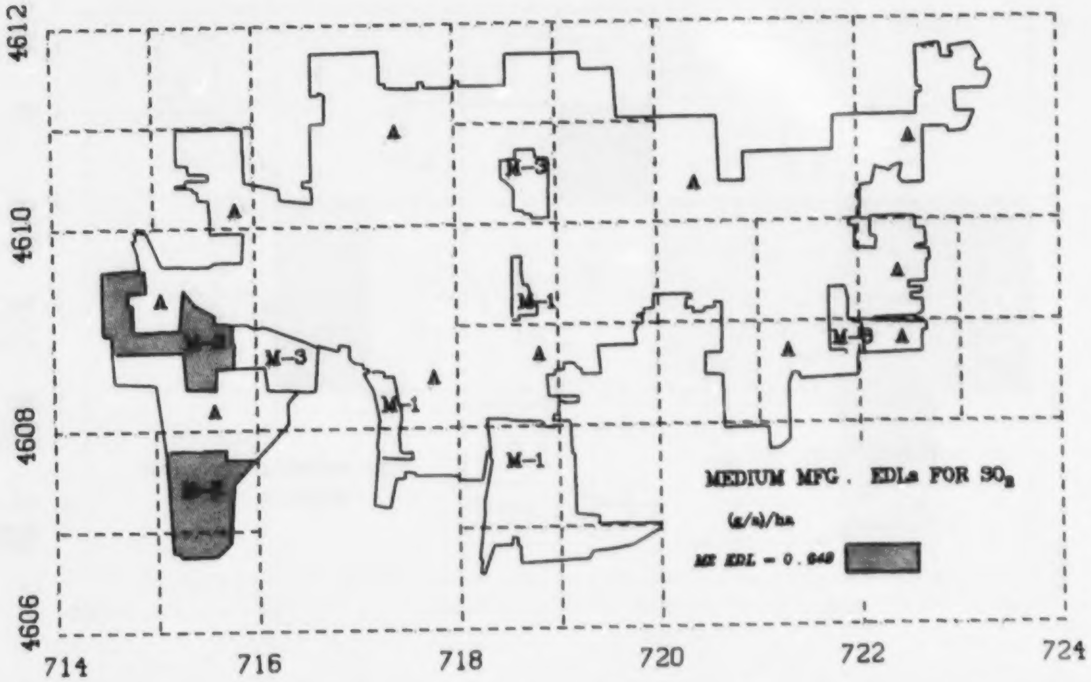
4612
4610
4608
4606
714
716
718
720
722
724
A
M-3
M-1
M-2
M-3
M-1
M-1
M-2
M-3
MEDIUM MFG. EDLs FOR SO$_2$
(g/s)/ha
M2 EDL = 0.049

Fig. 158. Step 24: Map of SO₂ EDLs for Medium Manufacturing in Cleanair City

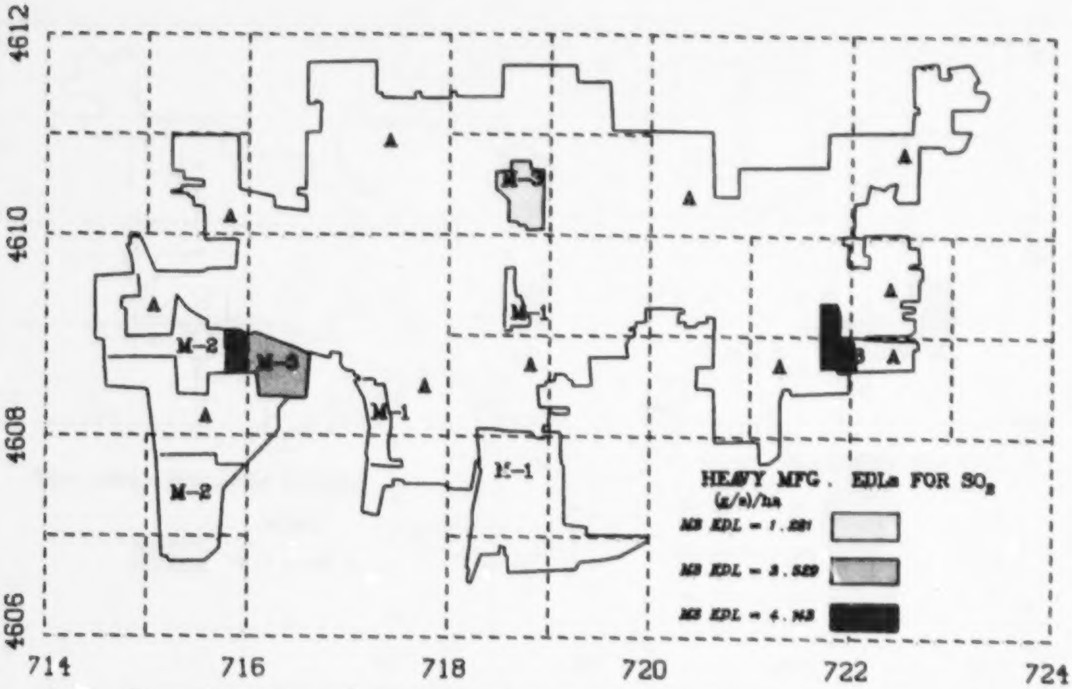
4612
4610
4608
4606
714
716
718
720
722
724
M-3
M-1
M-2
M-3
M-1
M-1
M-2
3
HEAVY MFG. EDLs FOR SO_2
(g/s)/ha
M3 EDL = 1.281
M3 EDL = 3.529
M3 EDL = 4.143

Fig. 159. Step 24: Map of SO_2 EDLs for Heavy Manufacturing in Cleanair City

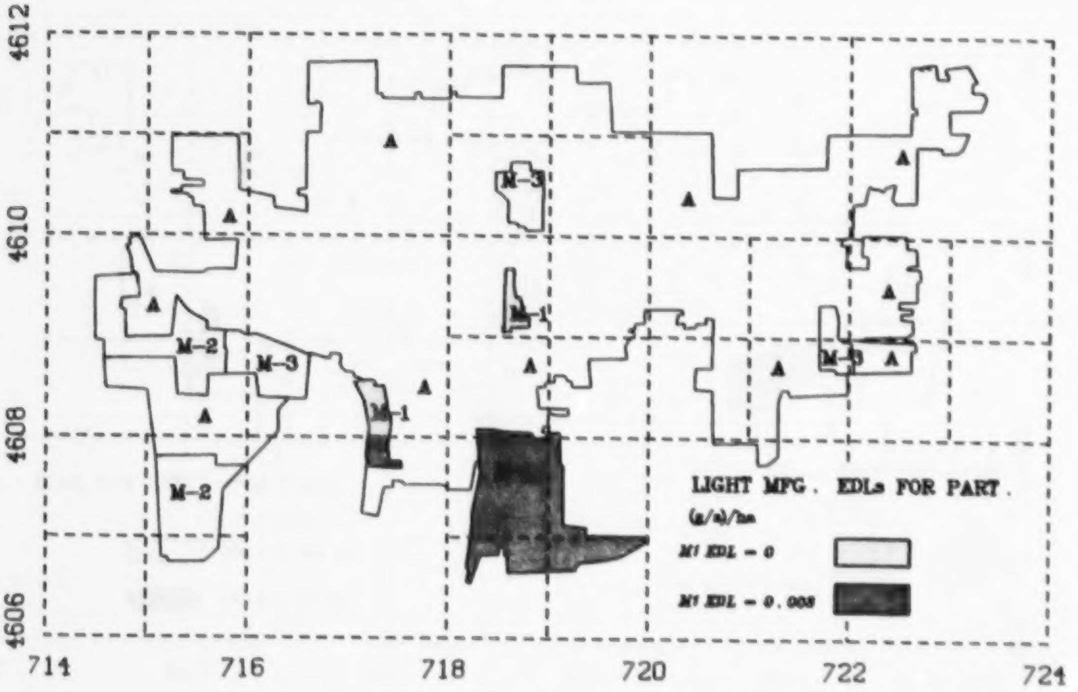
4612
4610
4608
4606
714
716
718
720
722
724
M-3
M-1
M-2
M-3
M-1
M-2
M-3
LIGHT MFG. EDLs FOR PART.
(g/s)/ha
M1 EDL = 0
M1 EDL = 0.003

Fig. 160. Step 24: Map of Particulate EDLs for Light Manufacturing in Cleanair City

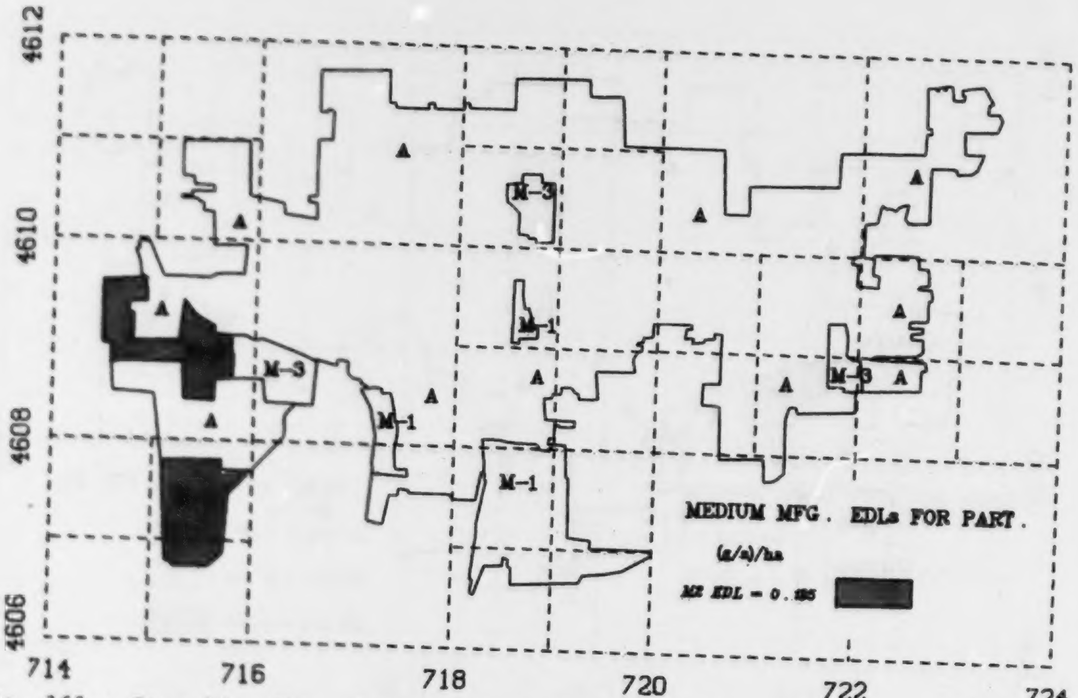
4612
4610
4608
4606
714
716
718
720
722
724
M-3
M-1
M-3
M-1
M-1
M-3
MEDIUM MFG. EDLs FOR PART.
(g/s)/ha
M2 EDL = 0.195

Fig. 161. Step 24: Map of Particulate EDLs for Medium Manufacturing in Cleanair City

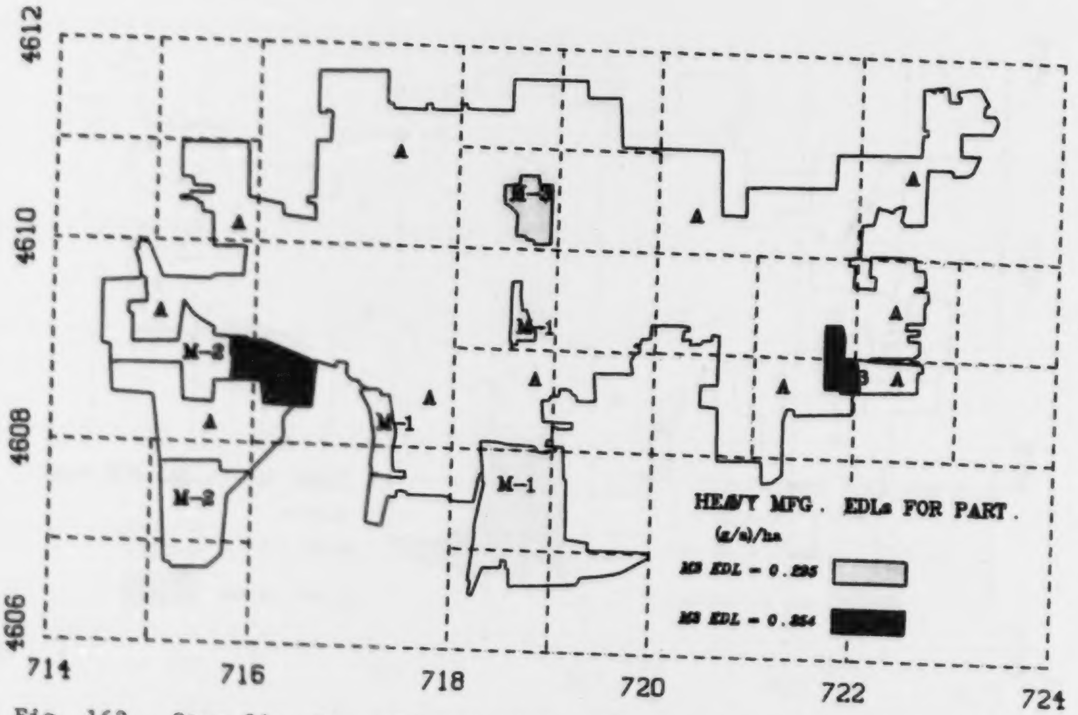
4612
4610
4608
4606
714
716
718
720
722
724
M-3
M-1
M-2
M-1
M-2
M-1
HEAVY MFG. EDLs FOR PART.
(g/s)/ha
M3 EDL = 0.295
M3 EDL = 0.354

Fig. 162. Step 24: Map of Particulate EDLs for Heavy Manufacturing in Cleanair City

REFERENCES

The following publications, referenced in the text of the guidebook, are recommended reading.

Benesh, F.H., et al., *Emission Density Zoning*, U.S. EPA Report EPA-450/3-77-006 (March 1977).

Berry, B.J.L., *Sampling, Coding, and Storing Flood Plain Data*, Agriculture Handbook No. 237, Economic Research Service, USDA (Aug. 1962).

Brail, R.K., *Land Use Planning Strategies for Air Quality Maintenance*, Proc. Specialty Conf. on Long-Term Maintenance of Clean Air Standards, Lake Michigan States Sec. of Air Pollution Control Assn., Chicago, J.J. Roberts, ed., pp. 275-289 (Feb. 1975a).

Brail, R.K., et al., *Emission Density and Allocation Procedures for Maintaining Air Quality*, U.S. EPA Report EPA-450/3-75-075 (June 1975b).

Chapin, Stewart, *Urban Land Use Planning*, 2nd Ed., p. 296, University of Illinois Press, Urbana (1972).

Cohen, A.S., et al., *Chicago Air Pollution Systems Analysis Program: Long-Range Planning in Air Resource Management*, Argonne National Laboratory Report ANL/ES-CC-008 (Jan. 1971). See Sec. 3; Zoning Survey -- Procedure and Application.

Goodman, William, and E.C. Freund, eds., *Principles and Practices of Urban Planning*, 4th Ed., International City Manager's Assn., Washington, D.C. (1968).

Hadfield, S.M., *Land Use Updating Survey*, Chicago Area Transportation Study (Dec. 1966).

Harvard University, *Users Reference Manual for Synagraphic Computer Mapping, "SYMAP," Version V*, Laboratory for Computer Graphics and Spatial Analysis, Cambridge, Mass. (1968).

Jaffe, M.S., et al., *Legal Aspects of Emission Density Zoning*, report prepared by American Society of Planning Officials for Argonne National Laboratory (1978).

Larsen, R.K., *A Mathematical Model for Relating Air Quality Measurements to Air Quality Standards*, U.S. EPA Report Number AP-89 (NTIS PB 205277) (Nov. 1971).

Robinson, A.H., and R.D. Sale, *Elements of Cartography*, 3rd Ed., John Wiley & Sons, Inc. New York, N.Y. (1969).

Additional Recommended Reading

The following publications also are recommended reading:

Benesh, F.H., et al., *A Review of Considerations and Issues in Emission Density Zoning*, GCA Corp., Bedford, Mass. 01730 (June 1977).

Cosier, *Land Use Based Emissions Strategies: Their Promise and Problems*, Planning Comments, *12*(2):31-47 (Fall 1976).

Roberts, J.J., E.J. Croke, and S.W. Booras, *A Critical Review of the Effect of Air Pollution Control Regulations on Land Use Planning*, APCA Critical Reviews #3 - Air Quality Management and Regional Land Use, 1975. Originally appeared in J. Air Pollution Control Assn., *25*(5):500-520 (1975).

Stiftel, Bruce, *Estimating the Impact of Emission Density Zoning on an Air Quality Maintenance Area: Proposal for Decision Tools*, U.S. EPA Office of Air Quality Planning and Standards working paper, Research Triangle Park, N.C. 27711 (revised, Sept. 1977).